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User's Manual for DIODE

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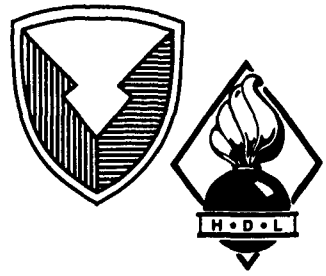

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This user's manual serves two main purposes: (1) to document the present DIODE computer program in preparation for proposed improvements and (2) to allow others to use the program without personal instruction.

Included are a brief history of the origin of the DIODE computer program, input data requirements, description of the computer code, output, and a discussion of the material parameters. Detailed instructions are included for the use of a remote IBM terminal on the Harry Diamond Laboratories site. Also included is a list of over 100 papers, reports, and oral presentations based on the DIODE program.

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1. Introduction and Background

The DIODE computer program at the Harry Diamond Laboratories (HDL) is used to compute current and voltage characteristics in semiconductors or gases. It has been used without change for approximately 12 years; improvements upon the program are overdue. This report documents the existing program and will serve as a basis upon which the improvements will be built. A listing of the computer code is provided in appendix A.

HDL's interest in the basic physical processes of electrical breakdown in gases arose from the need for sensitive trigger tubes for use in electrostatic fuzes. The initial theoretical work was based on papers by Varney et al [1] and by Crowe et al [2]. In the mid-1950's, Professor William Dow, Chairman of the Electrical Engineering Department at the University of Michigan and member of the Scientific Advisory Board of the Diamond Ordnance Fuze Laboratories (the predecessor of HDL), suggested that the problem could best be solved on the then-new electronic computers. Ward modified the formulation of Crowe et al to apply to the rare gases and used the National Bureau of Standards (NBS)* SEAC (South East Automatic Calculator) computer to calculate results. In order to extend the calculations to higher current densities, Ward included the space charge of electrons and reformulated and encoded the problem for the IBM 704 computer.

Time dependence was included for the first time when Börsch-Supan and Oser [3] wrote the basic program that is still in use. Thanks to the insistence of Irene Stugun, then chief of the NBS programming section, the basic continuity equations were used, rather than the partially integrated equations used previously. Over 100 papers, reports, and oral presentations (see bibliography) have resulted from the DIODE program.

In the summer of 1965, a summer student at HDL, Edward R. Berman, modified the program to include semiconductors [4]. The major changes were the inclusion of ionization by holes and the use of double precision because of the higher densities present in semiconductors. In 1969, under the direction of Burton Udelson, Howard Bloom [5] modified the external circuit of DIODE in order to study IMPATT oscillators. Bloom's report includes a full program listing. Since that time, Ward [6] added thermal effects to the program. Until 1988, computer cards were used for the input data. Now the program may be used in the time-sharing mode at a remote terminal.

Before the computer code and its use are discussed, we present the mathematics that forms the basis of the program. We then discuss in detail the format of the input data required to run the program; the

*Now the National Institute for Standards and Technology (NIST).

input data required consist of physical properties of the material studied and device descriptions. The information must be supplied by the user; HDL users can build on datasets previously used, changing only the information necessary. The output produced by the program is then described in detail (an example of the output is provided in app B).

As an aid to users in devising input datasets, we include information on the material parameters that have been commonly used; this information includes both data and suggestions on how to choose constants based on various earlier efforts.

Finally, we discuss the interactive use of DIODE as it has been implemented on HDL's IBM 3090 mainframe. These instructions are particular to HDL users, but non-HDL users may find them useful if they intend to implement the program elsewhere.

2. Formulation of Computer Program

2.1 Basic Equations

The one-dimensional continuity equations for electrons and holes, respectively, in a semiconductor are

$$\frac{e\partial n}{\partial t} = \frac{-\partial J_-}{\partial x} + \alpha J_- + \beta J_+ - R \quad , \tag{1}$$

$$\frac{e\partial p}{\partial t} = \frac{\partial J_+}{\partial x} + \alpha J_- + \beta J_+ - R \quad , \tag{2}$$

where x and t are the space and time coordinates, e is the electron charge, n and p are the electron and hole number densities, α and β are the ionization coefficients for electrons and holes, and R is the recombination rate. The electron and hole current densities, J_- and J_+, are given by

$$J_- = ne\mu_- E - eD_-\left(\frac{dn}{dx}\right) \quad , \tag{3}$$

$$J_+ = pe\mu_+ E - eD_+\left(\frac{dp}{dx}\right) \quad , \tag{4}$$

where μ_- and μ_+ are the electron and hole mobilities, D_- and D_+ are the diffusion coefficients, and E is the electric field.

Space-charge effects are determined by the one-dimensional Poisson equation

$$\frac{dE}{dx} = \frac{e(n - p + N)}{\kappa\varepsilon_0} \quad , \tag{5}$$

where κ is the dielectric constant for the semiconductor, e_0 is the permittivity of free space, and $N(x)$ is the distribution of net fixed charge. The sign convention in equations (1) through (5) is chosen so that E, J_- and J_+ are all normally positive quantities.

The one-dimensional thermal diffusivity equation is

$$\rho c\left(-\frac{\partial T}{\partial t}\right) = JE + k_T\frac{\partial^2 T}{\partial^2 x} + \frac{\partial k_T}{\partial T}\left(\frac{\partial T}{\partial x}\right)^2 , \tag{6}$$

where T is the temperature, J is the total current density, ρ is the semiconductor density, c is the heat capacity, and k_T is the thermal conductivity.

It may be shown from equations (1) through (5) that the total current density,

$$J = J_- + J_+ + \kappa\varepsilon_0\left(\frac{dE}{dt}\right) , \tag{7}$$

is a constant in space. This merely expresses current continuity in one dimension. The accuracy of the calculations may be monitored by the constancy of J across the width of the diode.

The variation of the intrinsic density with temperature was chosen as

$$n_i^2(T) = 2\times 10^{20}\left(\frac{T}{300}\right)^3 \exp\left[\left(\frac{E_g}{k}\right)\left(300^{-1} - T^{-1}\right)\right] , \tag{8}$$

where E_g is the bandgap energy of silicon. The variation of the injected (thermally generated) current density with temperature was assumed to be the same as for $n_i^2(T)$, since $np = n_i^2$ and the majority carrier density is fixed by the doping level.

2.2 Supplementary Equations

The cathode ($x = 0$) to anode ($x = d$) distance is divided into M equal intervals of width Δx. Initial ($t = 0$) arrays of $M + 1$ values must be given for n, p, and T, and a similar array given for the fixed charges, $N = N_D - N_A$, where N_D is the net number density of donors and N_A is the net number density of acceptors.

Two boundary conditions are required for equations (1) and (2). the electron current density at $x = 0$ and the hole current density at $x = d$. Alternatively, the number densities can be given and the current densities calculated from equations (3) and (4). At present, the boundary currents are constant in time.

The boundary condition for equation (5) is supplied by the total voltage across the diode. The initial voltage across the diode must be

given, and the voltage for later times is determined by the external circuit. Optional external circuits are available, but for this report, the diode, shunted by a capacitance, C, is in series with a load resistance, R_s, and a voltage source, $V(t)$. The voltage source may be constant in time, have one discrete step, or have an incremental sinusoidal variation. The last option allows a constant dV/dt value to be closely approximated.

3. Input Data

The input data for DIODE are formulated on 21 lines, preceded by a title line, and followed by a variable number of doping distribution and possibly temperature distribution lines. The final line is an ending indicator. The data field is justified right and uses standard Fortran criteria for digital data and integers. The standard line uses five number fields of 14 spaces each; i.e., numbers end on spaces 14, 28, 42, 56, and 70. Care must be taken that exponents end at the correct position, since zeros are read in blank spaces. Some lines have integers both in space 1 and in space 80.

Table 1 lists the 21 lines with a short identifying name. In the field width column, an integer in space 1 is indicated by "I" and in space 80 by "I*." In the descriptions that follow, consult table 1 to see the format and the array of parameters.

Title line. On the title line, the first character must be in space 1; a maximum of 71 characters is allowed. Typically, such information as the date of the run and the diode characteristics would be entered in the title line.

Lines 1 to 3. On lines 1, 2, and 3, enter the avalanche (that is, ionization by collision) coefficients for electrons, α (parameters A1 to A5); holes, β (parameters B1 to B5); and gas excitation, δ (parameters D1 to D5); respectively. (Since the format is the same for each of these lines, only line 1 is described.) When $\alpha = 0$, alpha parameter MODA should be set at zero, and A1 and A5 are irrelevant. MODA should be set to 1 if

$$\alpha = p\,\mathrm{A1}\exp\left(\frac{-\mathrm{A2}\,p}{|E|}\right), \qquad \text{if } \frac{|E|}{p} \le \mathrm{A5}\,, \tag{9}$$

$$\alpha = p\,A3\exp\left(\frac{-A4\,p}{|E|}\right), \qquad \text{if } \frac{|E|}{p} > A5\,, \tag{10}$$

where p, the gas pressure, is set equal to 1 for semiconductors, and E is the electric field.

If rare gases are being used, MODA should be set to 2; in this case, $(|E|/p)^{1/2}$ replaces $|E|/p$ in equations (9) and (10).

Table 1. Input format

Line	Name	Width of field[a]	Parameter (integer)	Computer fields 1	2	3	4	5	6	7	8
—	Title	—	—	—	—	—	—	—	—	—	—
1	Alpha	14I	MODA	A1	A2	A3	A4	A5	—	—	—
2	Beta	14I	MODB	B1	B2	B3	B4	B5	—	—	—
3	Delta	14I	MODD	D1	D2	D3	D4	D5	—	—	—
4	Temperature	14I	MODT	CAT	CBT	PWRM	PWRP	TEMP K	—	—	—
5	Material	13	—	DENSITY	SPEC HT	THRM CND	—	—	—	—	—
6	Hole mobility	14I	MODVP	MUP	C1	C2	C3	C4	—	—	—
7	Hole mobility 2	14I	MODVNP	MUP0	AVP	NOP	VPIM	—	—	—	—
8	Electron mobility	14I	MODVM	MUM	C5	C6	C7	C8	—	—	—
9	Electron mobility 2	14I	MODVNM	MUM0	AVM	NOM	VMIM	—	—	—	—
10	Mobility 3	14	—	C9	C10	C15	C20	—	—	—	—
11	Secondary	13	—	GAMSEC	TANSEC	GAMMA	GAMI	JMOJPO	—	—	—
12	Voltage	13	—	USTAT	DU	V0	OMEGA	T1	V	—	—
13	Harmonics	13I*[b]	IFOUR	V1	OMEGA1	PHI1	V2	OMEGA2	PHI2	—	—
14	Geometry	13	—	P	D	S	T	DVDT	JMAX	—	—
15	Circuit 1	13	—	R	L	C1	VC1	DVC1C	C	—	—
16	Circuit 2	13	—	R2	L2	C2	VC2	DVC2C	C	—	—
17	Circuit 3	13	—	R3	L3	C3	VC3	DVC3C	C	—	—
18	Miscellaneous	10	—	STEPFA	DJMAXM	DIELK	DENSPL	DENSMI	DENS2	REC	EGAP
19	External print	3	—	[See table 2]	—	—	—	—	—	—	—
20	Integer	3	—	M	PRTFRQ	N3S	MODP	MODFCH	EXTRAP	MS	IPOINT
21	TPRINT LIST	[See explanation, sect. 3]									
[—	Doping and temperature distribution lines follow.]										

[a] *I means that first number in field is an integer.*
[b] *I* means that number in column 80 is an integer.*

The program computes A6 internally to ensure continuity in α at A5; the result is included in the printed output.

Since

$$A6 = -A5\,[\ln A1 - \ln A3 - A2/A5]\ ,$$

one must not set A5 equal to zero. MODA should be set to 3 if

$$\alpha = p\,A1 \exp\left(\frac{-A2\,p}{|E|}\right) + p\,A3 \exp\left(\frac{-A4\,p}{|E|}\right)\ .$$

If MODA is set to 4, $(p/|E|)^{1/2}$ replaces $p/|E|$.

Lines 2 and 3, for holes and excitations, respectively, pertain to the same equations as line 1 (for electrons).

Line 4. On line 4, you supply data needed for temperature effects. If the temperature is constant in space and time, the temperature parameter MODT should be set to 0; put the temperature value in TEMPK, the last field in the line. If you calculate that the temperature will change as a result of power dissipated, set MODT = 1. In CAT, put the fractional change in A1 for a one-degree increase in temperature, and in CBT put the fractional change in B1. In PWRM, put the power-law dependence of the low field mobility of electrons upon temperature, i.e., $m_o(T) = m_o(300)T^{PWRM}$. Likewise, in PWRP, put the exponent for the hole mobility. If you are generating an initial distribution of temperature after the doping concentration lines, MODT must be set to 2 (see discussion of "*Other lines*" at the end of this section).

Line 5. On line 5, you enter the material parameters of density, specific heat, and thermal conductivity. These parameters do not change with temperature in the DIODE program.

Lines 6 to 10. On lines 6 through 10, you enter data describing the variation of the electron and hole mobility with field and doping level. If the hole mobility, μ_p, should be calculated according to

$$\mu_p = MUP\,(1 - C1 \cdot E)\ , \qquad E \le C3 \qquad (11)$$

$$\mu_p = C2 \cdot E^{-1/2}\,(1 - C9 \cdot E)^{-3/2}\ , \qquad E > C3\ , \qquad (12)$$

MODVP should be set to 0 (line 6). The computer calculates C9 to ensure continuity of μ_p at E = C3, and C9 is printed out.

If you set MODVP to 1, you must enter C9 and C15 in line 10. Then the computer solves equations (11) and (12) to obtain continuity in μ_p and $d\mu_p/dE$ over the range from E = C3 to E = C15 for the power law

$$\mu_p = C11 + C12 \cdot E + C13 \cdot E^2 + C14 \cdot E^3 \qquad (13)$$

and prints out C11 to C14.

The last parameter on line 6, C4, is the maximum hole velocity, usually termed saturation velocity, to be used in the field range for equation (12). Since a peak velocity at low fields can exceed the saturation velocity, as is the case for electrons in GaAs, the maximum hole velocity does not apply for fields less than C3 (eq (11)).

If you set MODVNP to 0, in line 7, the hole mobility is independent of the doping concentration at that position. If you set MODVNP to 1, the dependence is given by the other parameters. (This option has not proven useful for several reasons and will not be detailed here.)

Lines 8 and 9 include the parameters determining the electron mobility, μ_n. The equations are in the same form as equations (11) to (13):

$$\mu_n = \text{MUM}\,(1 - \text{C5}\cdot E)\ , \qquad E \le \text{C7}\ , \qquad (14)$$

$$\mu_n = \text{C6}\cdot E^{-1/2}(1 - \text{C10}\cdot E^{-3/2})\ , \qquad E > \text{C7}\ , \qquad (15)$$

$$\mu_p = \text{C16} + \text{C17}\cdot E + \text{C18}\cdot E^2 + \text{C19}\cdot E^3\ , \qquad \text{C7} < E < \text{C20}\ . \qquad (16)$$

Line 10 has been covered above.

Line 11. You would use line 11 primarily for secondary processes in gases. However, for semiconductors, JMO and JPO are the boundary values for the electron current density at the negative electrode and the hole current density at the positive electrode, respectively. These are used primarily under reverse bias.

Line 12. You enter voltage parameters on line 12. The external circuit used in DIODE is shown in figure 1 (many of the labels on figure 1 correspond to parameters on line 12; see table 1). USTAT is the initial source voltage and V is the initial voltage across the diode. At the time T1, a voltage increment DU is added to USTAT. You may also add a sinusoidal voltage to USTAT, so that the total applied voltage is

$$\text{USTAT} + \text{V0}\sin\text{OMEGA}\,t\ , \qquad (17)$$

where t is the problem time. You may use this option to apply a constant dV/dt, since for OMEGA $t \ll 1$, dV/dt is essentially equal to V0 OMEGA.

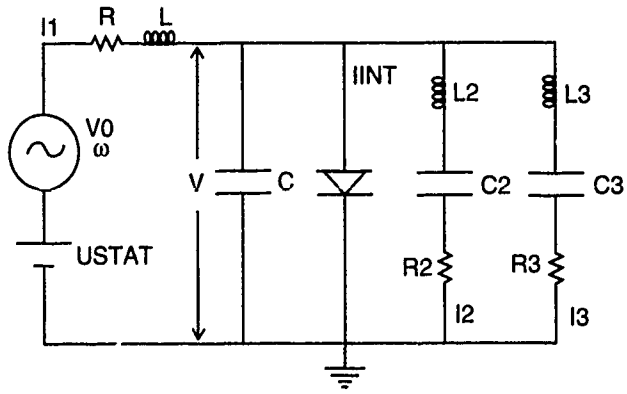

Figure 1. Circuit model used in DIODE.

Line 13. You may apply other frequencies, usually harmonics, by using line 13. PHI1 and PHI2 are the phase lags, with reference to OMEGA, for OMEGA1 and OMEGA2, respectively. IFOUR may be set at one to calculate the efficiency of oscillations at the frequency OMEGA and its second harmonic. If IFOUR = 1, the computer calculates a cosine instead of sine in equation (17). IFOUR is in column 80 of line 13.

Line 14. Enter geometrical information for the diode on line 14. P is the gas pressure in torr and should be set equal to 1.0 for semiconductors. D is the device width in centimeters. S is the device area in square centimeters. T allows a time other than zero to be the initial time (this is useful in extending a previous run or changing the phase of a sinusoidal voltage). DVDT is the initial dV/dt used in the start of the problem; it determines the displacement current at zero time, but setting $dV/dt = 0$ or 1×10^{12}, for example, makes little difference in most problems. JMAX is used to stop calculations when unreasonably high current densities are calculated, as occurs for instabilities. When JAVE (see sect. 4) exceeds JMAX, the calculations are halted and the results of that time step are printed out.

Lines 15 to 17. Lines 15 to 17 are used to describe the external circuit. The format for each line is identical, and each R, L, and C is shown in figure 1. VC and DVC are the initial voltage and dV/dt on each capacitor, used mainly for extensions of previous runs. C in figure 1 is given by C on line 17. Values of C on lines 15 and 16 are ignored. (The RLC circuit 2 has proven useful to simulate a resistive load, but not as a resonant circuit, because transients last too long for the calculation to be cost effective. We plan to modify the external circuit portion of the program by removing RLC circuit 3, removing L from the supply circuit, and adding L1 and R1 to the diode leg; see fig. 2.) To remove C2 and C3 from their respective legs (see fig. 1), set them greater than 1×10^{10} F.

Line 18. Miscellaneous decimal data are entered on line 18. STEPFA, or F, indicates the fraction of one distance step, Δx, that the electron (or hole) with the highest velocity, v_{max}, travels in one time step, Δt. This follows from the calculation of Δt from

$$\Delta t = F(\Delta x)/v_{max} \quad . \tag{18}$$

The factor F may be used to ensure that the calculation time step is less than the dielectric relaxation time [7]. To ensure symmetric diffusion, you should set $F = 1/2$ [8].

DJMAXM is a check on too rapid a current increase in one time step. If the new current exceeds the old current by a factor greater than DJMAXM, DT is halved and the computation repeated. The problem is terminated after three failures. DIELK is the dielectric constant of the semiconductor. DENSPL is the carrier density of holes, in cm^{-3}, at

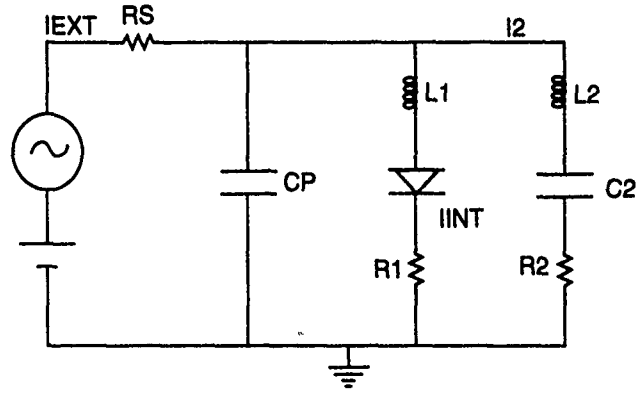

Figure 2. Proposed circuit model for DIODE, adding capability for including series resistance and inductance.

the right boundary, and DENSMI is that of electrons at the left boundary. In practice, these are used for forward-biased diodes only. DENS2 is the square of the intrinsic density at 300 K. REC is the recombination rate for the semiconductor. The lifetime in intrinsic material is given by $(2\ \mathrm{REC})^{-1}$. The minority lifetimes of electrons, t_n, and holes, t_p, are given by

$$t_n = n_i/(\mathrm{REC})\, p_o \ ; \quad t_p = n_i/(\mathrm{REC})\, n_o \ , \tag{19}$$

where n_i is the intrinsic density and p_o and n_o are the majority carrier densities. Finally, EGAP is the energy band gap in the semiconductor (see eq (8)).

Line 19. Line 19 determines the parameters to be printed out as a function of distance, x, at selected time intervals. The first two parameters are permanently selected to be x and E, the electric field. Users can choose six additional parameters to be printed out from the list of 20 given in table 2.

Line 20. Line 20 includes 8 integers. M is the number of space intervals, $\Delta x = d/M$. $M + 1$ values of each distribution parameter must be included in the input data (see below, *Other lines*).

PRTFRQ is the print frequency: When PRTFRQ is set to 1, $M+1$ values are printed out; for PRTFRQ = 2, $M/2 + 1$ values are printed, and so on for higher values of PRTFRQ.

N3S is the number of triples to be included on line 21 (see discussion of line 21).

MODP is the mode of printout: If MODP is set to 1, the printout is according to time; if MODP = 2, the printout is according to current (see discussion of line 21).

MODFCH determines whether fixed charges, as for doped semiconductors, are to be included. If MODFCH = 0 or 1, no fixed charges are included; if MODFCH > 1, you must supply fixed charges to simulate the device doping.

Table 2. Parameters in TPRINT LIST (line 21) that cause optional output data to be printed

Note: A maximum of six may be chosen.

Option No.	Name	Meaning
1	ALPHA	Electron ionization coefficient, α
2	BETA	Hole ionization coefficient, β
3	UNIVD	Excitation coefficient, δ
4	VM	Electron velocity
5	VP	Hole velocity
6	ALPHA * J–	$\alpha J_-(X)$
7	BETA * J+	$\beta J_+(X)$
8	NP – NM + DN	$N_+(X) - N_-(X)$ + doping density
9	RECOM RATE	Recombination rate
10	JP DIF	Hole diffusion current density
11	JN DIF	Electron diffusion current density
12	J DISPL	Displacement current density
13	J TOTAL	Total current density
14	V SUM	Voltage distribution
15	DVXDT	dV/dt
16	N+(X)	Hole number density
17	N–(X)	Electron number density
18	J+(X)	Hole current density
19	J–(X)	Electron current density
20	TEMP	Temperature

EXTRAP allows extrapolations to be used instead of the boundary conditions given in line 11 or 18. If EXTRAP is set to 0, the conditions in lines 11 and 18 are used; otherwise the extrapolations are used. (The extrapolation option has rarely been used.)

MS sets a limit on the number of consecutive time steps in which a negative field is calculated. Calculation is halted when MS is exceeded, and an error message is given.

Last, IPOINT gives the number of time steps to be used in the summary printout. See section 4 on output.

Line 21. On line 21 you give instructions for the intervals between the time steps for which you want data printed out. These instructions, called the TPRINT LIST, are composed of "triples": two real numbers (including a decimal point) and one integer compose one triple. (The number of triples, N3S, was specified in line 20.)

If MODP (also in line 20) is set to 1, the results of the run are printed out according to time. In this case, each triple is interpreted as follows: the first number is the time for the initial printout and ends on space 14 of line 21. The second number is the time interval between subsequent printouts and ends on space 28. The integer gives the number of time intervals for that triple and ends on space 31. (The second triple, if used, gives the same information, but the numbers end in spaces 50, 64, and 67.)

If MODP = 2, the results are printed out according to current density. In this case, the first number in the triple gives the current density for the first printout, the second number gives the multiplier for subsequent printouts, and the integer gives the total number of printouts. (The spacing of the fields is the same as for MODP = 1.) If MODP = 2, then JMAX on line 14 gives the maximum problem time in seconds. Additional lines may be used if more than two triples are desired.

Other lines. Following TPRINT LIST on line 21, you can use a variable number of lines to simulate the desired initial distributions of holes, electrons, doping levels, and, if MODT = 2 (line 4), temperature. You may use $M + 1$ numbers, 5 to a line, to the various densities, given in units of cm^{-3}. The first density number must end on space 14, and other numbers on multiples of 14. Enter the hole distribution first; the electron distribution follows, starting with a new line. The net doping concentration follows; a negative sign indicates acceptors or *p*-type material. Enter the initial temperatures in kelvins.

Ending line. Following the distributions is an ending line. If you set ENDING to <10,000, the program executes another run. If ENDING exceeds 10,000 but is less than 32,767, the program stops.

4. Output

The output of DIODE consists of a printout with three parts: the input data, the distribution data at selected times, and the temporal results. Appendix B is a portion of the program output for a sample problem.

The initial page of the input data is headed by the title line, reproduced from the input. Each of the input lines is then listed in a format similar to the input and identified by the labels shown in table 1. (There is one exception in the order of lines: line 20 of table 1 precedes line 19.) The TPRINT LIST (line 21) prints out the times as determined by the triples. Following the TPRINT LIST, the values of A6, B6, D6, and C9 to C19 are printed out. (These constants are explained following eq (10) and also in eq (13).)

The second page of the printout of the input data is headed by the initial time and voltage. Then the distributions follow in columns headed by M, N+, N–, DN, and TEMP K. The grid points range from 0 to M, for M + 1 values. N+, N–, DN, and TEMP K are the input densities of holes, electrons, and fixed charges, and the temperature, respectively.

The distribution data then follow—one page for each time listed on the TPRINT LIST. There are four heading lines at the top of the page. Line 1 includes T (time), V (diode voltage), U (applied voltage), J+AVG

(average hole current density), J–AVG (average electron current density), J AVG (J+AVG + J–AVG), and GAMMA (used only for gas excitations).

Line 2 includes DT, the time step; V+MAX, the maximum hole velocity for that time step; V–MAX, the maximum electron velocity; I EXT, the maximum current through resistor R; I INT, the maximum current through the diode; J INT, the average current density (including the displacement and diffusion current densities); and DV/DT, the rate of voltage rise across the diode.

Line 3 includes D*ALPHAAVG, the integral of $a\,dx$; A*J–AVG, the average value of αJ_-; D*BETAAVG, the integral of $b\,dx$; B*J+AVG, the average value of bJ_+; RECOMRATAVG, the average rate of electron-hole recombination; I23, the sum of currents through circuits 2 and 3; and DI/DT, the rate of current rise through the diode.

Line 4 includes J+DIF, the hole diffusion current density (calculated from the Einstein equation and dp/dx and averaged); J–DIF, the electron diffusion current density; J DIF, the total diffusion current density; J DISPL, the displacement current (calculated from dE/dT); AVE TEMP K, the average temperature across the diode; TEM RATE, the rate of temperature increase, in kelvins per nanosecond; and DENS2T, the square of the intrinsic density at the average temperature.

The main part of the distribution data at specified times is arranged in columns, where the number of rows = (M + 1)/PRTFRQ. The first two columns are fixed and are headed X (distance) and E(X) (field). The distance is given in centimeters and the field in volts per centimeter. The other six columns are chosen by the user from the options shown in table 2.

The page following the distribution data is headed by "capacitor voltages at last successful printout." It is followed by the voltages and dV/dT for the capacitors used in circuits 2 and 3. The final page (or pages) of the printout consists of six columns of data printed according to time. The number of times printed is the value of IPOINT (line 20); the times are equally spaced between the initial time and the maximum time, as selected by the TPRINT LIST. The first column is headed by T and lists the time. The second column is headed by V and lists the voltages for each time. The third column is headed by I and lists the diode total current. The fourth is headed by JAVG and is the sum of the electron and hole current densities. The fifth column is headed by I1 and lists the current through the external circuit (see fig. 1). The last column is headed by I2 and lists the current through circuit 2. This completes the printout for the program DIODE.

5. Material Parameters

The first 10 lines and line 18 of the input data (see table 1) contain the material parameters for the semiconductor of interest. Table 3 contains the input avalanche parameters for silicon and gallium arsenide which have been most commonly used. Table 4 contains the parameters used for the variation of mobility with field. For silicon, parameters are given for high-mobility (ideal) and low-mobility (practical) material. Other material parameters (lines 4, 5, and 18) are given in table 5. The temperature parameters are unknown for GaAs, and so the silicon values are used.

From equation (11), the hole velocity, v_p, is given by

$$v_p(E) = \text{MUP} \cdot E[1 - (\text{C1})E] \ , \quad E \le \text{C3} \ . \tag{20}$$

Thus the hole velocity is parabolic with a maximum velocity, $v_{max} = \text{MUP}/4 \cdot \text{C1}$, at the field $E_{max} = 1/2(\text{C1})$. These two equations for C1 are usually not compatible, and therefore C3 must be chosen less than E_{max} and equation (13) used to fit the experimental curves. Generally, v_p calculated from equation (12) will exceed C4 (v_{max}) where E is slightly more than C7. The same considerations apply to choosing constants in equations (14) to (16) to fit the experimental electron velocity versus field curves.

For fitting the electron velocity versus field curves for GaAs, or other negative differential velocity materials, the constant C10 in equation (12) must be chosen to be negative. Then equation (12) has a minimum velocity, v_{min}, at the field $E(v_{min})$. Then the fitting equations are

$$E(v_{min}) = -(2 \cdot \text{C10})^{2/3} \ ; \quad v_{min} = (3/2)\text{C6}[E(v_{min})]^{1/2} \ . \tag{21}$$

Again, trial and error will be required to obtain the best fit to experimental data.

The dependence of the low field mobilities of the electrons and holes upon temperature is given in table 4 as inverse to the 2.5 and 2.7 power, respectively. However, the saturation velocities vary approximately inversely with temperature. At present, the saturation velocities (C4 and C8 in table 4) are increased at higher temperatures to give rough agreement to this variation, since the saturation velocity is otherwise too low. A planned modification to the program will give a single expression [9] that gives the mobility variation with field, doping, and temperature.

Table 3. Parameters used for avalanche calculations

Variable	Value for silicon	Value for GaAs
MODA	1	1
A1	7.03×10^5	5.05×10^6
A2	1.231×10^6	1.95×10^6
A3	7.03×10^5	1.52×10^6
A4	1.231×10^6	1.60×10^6
A5	1.0×10^6	2.86×10^5
A6*	1.231×10^6	1.607×10^6
MODB	1	1
B1	1.582×10^6	2.05×10^7
B2	2.036×10^6	2.49×10^6
B3	6.71×10^5	1.49×10^6
B4	1.693×10^6	1.75×10^6
B5	4.0×10^5	2.82×10^5
B6*	1.693×10^6	1.75×10^6
CAT	2×10^{-3}	2×10^{-3}
CBT	2×10^{-3}	2×10^{-3}

**Computed*

Table 4. Parameters used for mobility calculations

Variable	Value for low-mobility silicon	Value for high-mobility silicon	Value for GaAs
MODVP	1	1	0
MUP	4.0×10^2	6.0×10^2	4.0×10^2
C1	2.0×10^{-5}	4.0×10^{-5}	1.0×10^{-5}
C2	1.6×10^4	1.7×10^4	4.47×10^4
C3	2.0×10^4	9.0×10^3	4.0×10^4
C4	1.0×10^7	1.0×10^7	1.0×10^7
MODVM	1	1	1
MUM	1.2×10^3	1.5×10^3	8.5×10^3
C5	4.4×10^{-5}	4.9×10^{-5}	1.0×10^{-4}
C6	4.4×10^4	4.4×10^4	1.0×10^4
C7	7.0×10^3	1.0×10^4	5.5×10^3
C8	1.0×10^7	1.0×10^7	1.0×10^7
C9	-1.55×10^7	-1.55×10^7	-4.77×10^6
C10	-1.30×10^6	-1.3×10^6	2.4×10^7
C15	1.0×10^5	1.2×10^5	5.0×10^4
C20	2.0×10^4	2.0×10^4	5.0×10^4
Computed parameters			
C11	2.90×10^6	1.78×10^6	0
C12	1.11×10^2	2.05×10^2	0
C13	-8.35×10^{-4}	-2.16×10^{-3}	0
C14	1.88×10^{-9}	7.37×10^{-9}	0
C16	1.97×10^6	1.34×10^7	2.63×10^7
C17	6.28×10^2	-1.42×10^3	-1.08×10^3
C18	-1.01×10^{-2}	1.09×10^{-1}	2.27×10^{-2}
C19	-1.76×10^{-7}	-2.44×10^6	-1.68×10^{-7}
Temperature parameters			
PWRP	2.7	2.7	2.1
PWRN	2.5	2.5	1.0

Table 5. Other material parameters

Name	Meaning	Units	Material	
			Silicon	GaAs
DENSITY	Density	g/cm^2	2.328	5.32
SPEC HT	Specific heat	J/g°C	0.70	0.35
THRM CND	Thermal conductivity	W/cm°C	1.45	0.46
DIELK	Relative dielectric constant	—	11.8	13.1
DENS2	Intrinsic density squared	cm^{-6}	2×10^{20}	3.2×10^{12}
EGAP	Energy gap	eV	1.12	1.43
CAT	Proportional change in temperature of α	—	2.0×10^{-3}	2.0×10^{-3}
CBT	Proportional change in temperature of β	—	2.0×10^{-3}	2.0×10^{-3}
PWRM	Mobility dependence on power of temperature for electrons	—	2.5	2.5
PWRP	Mobility dependence on power of temperature for holes	—	2.7	2.7

6. Using the Interactive Version of DIODE on an IBM Terminal

This section describes how to use a dedicated IBM terminal connected directly to the HDL IBM 3090 mainframe to access the DIODE program. Implementations of DIODE on other hosts will differ in detail from those given here (particularly instructions for logging on, etc). However, certain aspects of this description may apply to any implementation of the program.

This section covers procedures for logging on, defining the input data, and getting the output. It should be noted that this document gives only a cursory description of the IBM 3090's menu-driven work environment (ISPF—interactive system productivity facility) and of its editor, which are necessary to execute the program and specify the input. A fuller description of each can be found in standard IBM manuals available through the information management group at HDL or by contacting Steven Kaplan (ext. 41403).

6.1 Getting Started

These instructions assume a user with an IBM terminal that is directly wired to the HDL IBM 3090. The first step in using the DIODE code is to log onto the IBM time sharing option (TSO) and then get into the menu-driven mode called ISPF. The interactive version of DIODE currently resides only in the account HK1005. The instructions given here are easily generalized to include the code's use on other accounts.

The following steps are required to access the main ISPF menu:

(1) Turn on the terminal. Make sure the key (if there is one) is in the horizontal position. Hit RESET if the keyboard input is not being accepted. (If there is still a problem, contact user assistance, ext. 42940.)

(2) Type "LOGON" and then press ENTER.

(3) When prompted, type the userid (HK1005) and then press ENTER.

(4) When prompted, type the password (see Kaplan) and then press ENTER.

You should now be in TSO. After some system information and messages appear on the screen, the prompt "READY" should appear at the left end of the current line.

(5) At the READY prompt, type "SPF".

You should now see the main ISPF menu, which reads as follows:

ISPF PRIMARY MENU

OPTION ===>

0 ISPF PARMS

1 BROWSE

2 EDIT

3 UTILITIES

4 FOREGROUND

5 BATCH

6 COMMAND

7 DIALOG TEST

8 LM UTILITIES

C CHANGES

S SYSTEM APPLICATIONS

T TUTORIAL

U USER APPLICATIONS

X EXIT

The SPF menu has 14 options. At the arrow prompt on the top line, enter the number or letter corresponding to the desired option. The three options that are particularly important for using the DIODE program are listed below with brief descriptions of their respective functions.

Option	Mode	Description
1	Browse	Allows user to view a dataset
2	Edit	Allows user to view and change a dataset
6	Command	Allows user to execute a TSO command

The function (PF) keys at the top of your keyboard perform operations such as scrolling through datasets and moving between SPF modes. The PF3 key allows one to exit from the different SPF modes to the main menu. The uses of the most important function keys are as follows:

PF1 Help function

PF3 Exit current mode

PF7 Scroll up (edit/browse)

PF8 Scroll down (edit/browse)

PF10 Scroll left (edit/browse)

PF11 Scroll right (edit/browse)

The remainder of this section describes using the SPF options to run the DIODE program, and view or change its input/output.

6.2 How to Edit/Browse Datasets

To create or change an input file or examine an output file, you need to use the edit or the browse (no changes allowed) mode. The following describes how to access the edit mode. (To use the browse option, follow the same procedure, except enter option 1 at the top line of the SPF main menu.) To edit:

Enter option 2 at the arrow prompt on the top line of the SPF main menu. You must next specify the file to be edited. A dataset panel appears as follows:

ISPF LIBRARY

PROJECT ==> {enter userid}

GROUP ==> {enter filename}

TYPE ==> {enter file type}

The datasets that are relevant to DIODE are the following:

INDIOD DATA : input dataset

OUTDIOD.DATA : output dataset

SKDIOD.FORT : source code dataset

DIOD.CLIST : command list to run the program

So, for example, to edit the input dataset, the panel should look as follows:

ISPF LIBRARY

PROJECT ==> HK1005

GROUP ==> INDIOD

TYPE ==> DATA

After the panel is set up to indicate the appropriate dataset, hit ENTER. The dataset contents should appear on the screen. You can scroll through the dataset, and change its contents (if in edit mode). When editing, be sure to save your changes by typing "SAVE" at the command line prompt at the top of the screen. To exit, hit the PF3 key (this should also save the dataset, but use the save command to be sure).

Note: A detailed description of the editor commands, the function keys, or any other TSO/SPF functions can be obtained by contacting Steven Kaplan at extension 41403.

6.3 How to Run the Program

In the IBM account HK1005 there is a command list (clist) member called DIOD(RD) which automatically allocates the necessary datasets, executes the program, and prints the output. Variations in use of DIODE, such as incorporating different files for input and output, are easily accommodated by contacting Steve Kaplan (ext. 41403). To run DIODE using the existing clist, follow these steps:

(1) Starting from the SPF main menu (see sect. 6.1), get into the TSO command mode by entering option 6 at the arrow prompt on the top line.

(2) In TSO an arrow prompt will also appear. At this prompt, enter the following:

EXEC DIOD(RD)

where EXEC is the command to execute a clist and DIOD(RD) is the clist to be executed.

(3) When the run is completed, three asterisks (***) will appear. Hit the PF3 key twice to return to the SPF main menu.

6.4. Ending the Session

Starting from the main SPF menu:

(1) Type "x" or "end" at the arrow prompt, then hit ENTER.

The cursor should be at a field marked "PROCESS OPTION" in the subsequent panel. Enter one of the options listed in this panel; in general, either "D" (to delete the dataset containing the session input) or "K" (to keep the session input—this is usually unnecessary).

(2) You should now see the TSO "READY" prompt. Log off the system by typing "LO" and then ENTER.

7. The Program

The Fortran 77 program is divided into the main program with 263 source statements and 12 subroutines. The subroutines are listed in table 6 with the purpose and number of statements for each. Some statements consist of multiple lines.

The complete listing of the program is given in appendix A. A portion of the printout for a sample problem is given in appendix B.

If non-HDL readers are interested in implementing DIODE on other computers, they should contact the authors at HDL for a tape.

Table 6. Subroutines of DIODE

Title	No. of source statements	Purpose
INPUT	148	Reads and writes input data
INCON	103	Initial calculations
EXTCIR	37	Calculates effect of external circuit
TEST	72	Tests for various conditions
OUTPUT	87	Calculates and prints output data
ABD	8	Calculates ionization coefficients (eq (8), (9))
UNIV	24	Further ionization calculations
MUF	11	Calculates mobilities (eq (10)–(15))
TESTSQ	29	Gas excitation
SIMQ	53	Further gas excitation
EFFCY	98	Calculation of rf efficiency
BLKDT	20	Reserves memory blocks
Statements in main program:		263
Statements in subroutines:		690
	Total	953

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Appendix A.—Listing of Program DIODE

```
C     DIODE SPACE CHARGE PROGRAM FOR GASES AND SEMICONDUCTORS WITH DRIFT, A   1
C     IONIZATION AND RECOMBINATION AS A FUNCTION OF TEMPERATURE          A   2
      REAL ICUR,ICURO,IEXT,IINT,IINTO,I23,JAVG,JC,JCSAV,JDIF,JDISPL,JDIS A   3
     1SP,JINT,JM,JMAX,JMDIF,JMSAV,JMO,JP,JPDIF,JPSAV,JPO,MJDSP,MJM,MJMDF A   4
     2,MJP,MJPDF,MTEM,MUM,MUMO,MUP,MUPO,NM,NMSAV,NP,NPP,NPSAV,NOM,NOP,L, A   5
     3MUF,MUMF,MUPF                                                     A   6
      DIMENSION DVXDT(101),DNPDX(101),DNMDX(101),DIFP(101),DIFM(101),   A   7
     1GM(101),GP(101),JDISSP(101),DTEM(101)                             A   8
      INTEGER PRTFRQ,CHECK,ENDING,CHECK2,EXTRAP,CIRCT(10),CHECK1         A   9
      COMMON /ABC/ MODA,MODB,MODD,MODVP,MODVM,MODVNP,MODVNM,MODT,A1,A2,  A  10
     1A3,A4,A5,A6,B1,B2,B3,B4,B5,B6,D1,D2,D3,D4,D5,D6,C1,C2,C3,C4,C5,C6, A  11
     2C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,MUP,MUM,MUPO, A  12
     3MUMO,AVP,AVM,NOP,NOM,VP1M,VM1M,CAT,CBT,PWRP,PWRM,TEMP             A  13
      COMMON /CIRT/ USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2, A  14
     1RD,LD,R(3),L(3),C(3),CP,T1,IEFCY,VNEW                             A  15
      COMMON /DSTR/ NP(201),NM(201),DN(201),TEM(201),E(201),DE(201),VSUM A  16
     1(201),VP(201),VM(201),JP(201),JM(201),JPDIF(201),JMDIF(201),JDISPL A  17
     2(201),RCMBR(201),ALPHA(201),BETA(201),TPRINT(201)                 A  18
      COMMON /EFCY/ AMP,AMP2,PHASE,PJ,PV,PHASE2,PJ2,PV2,DTP,GNEG,RFP,EFF A  19
     1,AMPVDC,AMPJDC,DCPWR,AMPV,AMPV2                                   A  20
      COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ, A  21
     1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN A  22
     2SPL,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC         A  23
      COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT, A  24
     1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM, A  25
     2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO     A  26
      COMMON /PLO/ TIME(401),VOLT(401),CURR(401),JAVG(401),CURR1(401),  A  27
     1CURR2(401),CURR3(401),CLTT(401),TAVR(401)                         A  28
      COMMON /SAV/ NPSAV(101),NMSAV(101),ESAV(101),VXSAV(101),VPSAV(101) A  29
     1,VMSAV(101),JPSAV(101),JMSAV(101),VSAV,TSAV,JCSAV,GAMSAV,TMPSAV   A  30
C                                                                       A  31
      MUPF(Z)=MUF(Z,P,C1,C2,C3,C4,C9,MUP)                               A 31B
      MUMF(Z)=MUF(Z,P,C5,C6,C7,C8,C10,MUM)                              A 31C
2     UNIVA(EA)=UNIV(P,MODA,EA,A1,A2,A3,A4,A5,A6)                       A 31D
      UNIVB(EA)=UNIV(P,MODB,EA,B1,B2,B3,B4,B5,B6)                       A 31E
      UNIVD(EA)=UNIV(P,MODD,EA,D1,D2,D3,D4,D5,D6)                       A 31F
      BOLTZ=8.6E-5                                                      A  32
      ENDING=10                                                         A  33
10    CHECK1=0                                                          A 33A
      CALL INPUT(ENDING,CHECK1)                                         A 33B
      VNEW=V
      IF (CHECK1.EQ.1) GO TO 275                                        A 33C
C
C     SET COUNTERS                                                      A  34
C
      INSTEP=0                                                          A  35
      DT=0.                                                             A  36
      IINT=0
      DIDT=0
      DDIDT=0
      ISET=1                                                            A  37
      INDEX=1                                                           A  38
      MINUS=MS                                                          A  39
```

Appendix A

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      MSO=MS                                                                A  40
      CHECK=0                                                               A  41
      CHECK2=0                                                              A  42
C
C     COMPUTE CONSTANTS FROM INPUT                                          A  43
C
      CALL INCON(CIRCT,ENDING)                                              A  44
      IT=0                                                                  A  45
      DTP=(TPRINT(IJ)-TPRINT(1))/(FLOAT(IPOINT)-1.)                         A  46
      IF (INSTEP.EQ.0) GO TO 125                                            A  47
C     START OF COMPUTATION LOOP                                             A  48
110   INSTEP=1                                                              A  49
C     COMPUTE NEW TIME                                                      A  50
      DT=STEPFA*DX/VMAX                                                     A  51
      GO TO 123                                                             A  52
120   DT=DT/2.                                                              A  53
123   T=T+DT                                                                A  54
C     COMPUTE U                                                             A  55
      U=USTAT                                                               A  56
      IF (T.LT.T1) GO TO 125                                                A  57
      IF (IEFCY.EQ.0) GO TO 124                                             A  58
      U=U+DU+VO*COS(OMEGA*T)+V1*COS(OMEGA1*T+PHI1)+V2*COS(OMEGA2*T+PHI2)    A  59
      GO TO 125                                                             A  60
124   U=U+DU+VO*SIN(OMEGA*(T-T1))                                           A  61
125   CONTINUE                                                              A  62
      DO 126 I=1,MP1                                                        A  62A
      GP(I)=EL*NP(I)                                                        A  62B
126   GM(I)=EL*NM(I)                                                        A  63
C     CALCULATE RECOMBINATION RATE                                          A  64
      DENS2T=DENS2*(MTEM/300.)**3*EXP(EGAP/BOLTZ*(1./300.-1./MTEM))         A  65
      DO 128 I=1,MP1                                                        A  66
      NPP=NP(I)*NM(I)                                                       A  67
      IF (DENS2T.NE.0.) NPP=(NPP-DENS2T)/SQRT(DENS2T)                       A  68
128   RCMBR(I)=REC*EL*NPP                                                   A  69
      IF (INSTEP.EQ.0) GO TO 169                                            A  70
C     CALCULATION OF EXTERNAL CIRCUIT - V,JEXT                              A  70A
      CALL EXTCIR (ISET,CIRCT)                                              A  70B
C     HOLE CHARGE DENSITY                                                   A  71
      IF (EXTRAP.EQ.1) GO TO 130                                            A  72
      GP(MP1)=DENSPL*EL                                                     A  73
      GO TO 140                                                             A  74
130   GP(MP1)=GP(MP1)+(2.*JP(MP1)-3.*JP(M)+JP(M-1))*DT/DX                   A  75
140   SUM=(UNIVD(E(MP1))*JM(MP1)+UNIVD(E(1))*JM(1))/2.                      A  76
      DO 150 I=1,M                                                          A  77
      GP(I)=GP(I)+DT*(ALPHA(I)*JM(I)+BETA(I)*JP(I)+(JP(I+1)-JP(I))/DX)      A  78
150   SUM=SUM+UNIVD(E(I))*JM(I)                                             A  79
C     COMPUTE EFFECT OF PHOTONS HITTING CATHODE                             A  80
      RFAC=0.                                                               A  81
      IF (TAUSEC.NE.0.) RFAC=EXP(-DT/TAUSEC)                                A  82
      GAMMA=RFAC*GAMMA+GAMSEC*DX*(1.-RFAC)*SUM                              A  83
C     ELECTRON CHARGE DENSITY                                               A  84
      DO 160 I=2,MP1                                                        A  85
```

```
160   GM(I)=DT*(ALPHA(I)*JM(I)+BETA(I)*JP(I)-(JM(I)-JM(I-1))/DX)+GM(I)      A  86
      DO 162 I=1,MP1                                                        A  87
      GP(I)=GP(I)-DT*RCMBR(I)                                               A  88
162   GM(I)=GM(I)-DT*RCMBR(I)                                               A  89
C     TEST FOR NEGATIVE NUMBER DENSITIES                                    A  90
      DO 168 I=1,MP1                                                        A  91
      NP(I)=GP(I)/EL                                                        A  92
      NM(I)=GM(I)/EL                                                        A  93
      IF (NP(I).GE.0.) GO TO 165                                            A  94
      GP(I)=0.                                                              A  96
      NP(I)=0.                                                              A  97
165   IF (NM(I).GE.0.) GO TO 168                                            A  98
      GM(I)=0.                                                              A  99
      NM(I)=0.                                                              A 100
168   CONTINUE                                                              A 102
C     ELECTRIC FIELD                                                        A 103
169   ESTAR=0.0                                                             A 104
      E(1)=0.                                                               A 105
      E(2)=GM(1)+GM(2)-GP(1)-GP(2)-EL*(DN(1)+DN(2))                         A 105A
      DO 170 I=3,M                                                          A 106
170   E(I)=E(I-1)+(GM(I-2)+2.*GM(I-1)+2.*GM(I)+GM(I+1)-GP(I-2)-2.*GP(I-1   A 107
     1)-2.*GP(I)-GP(I+1))/3.-EL*(DN(I-1)+DN(I))                             A 107A
      E(MP1)=E(M)+GM(M)+GM(MP1)-GP(M)-GP(MP1)-EL*(DN(M)+DN(MP1))            A 107B
      DO 180 I=2,MP1                                                        A 107C
180   ESTAR=ESTAR+E(I-1)+E(I)                                               A 108
      E(1)=VNEW/D-CST(6,1)*ESTAR/(2.*FM)                                    A 109
      E(1)=E(1)-CST(6,1)*((GM(1)-GP(1)-GM(MP1)+GP(MP1)-EL*(DN(1)-DN(MP1))   A 110
     1))/(6.*FM))                                                           A 111
C     ADJUST E                                                              A 112
      DO 190 I=2,MP1                                                        A 113
      E(I)=CST(6,1)*E(I)+E(1)                                               A 114
190   VSUM(I)=VSUM(I-1)+0.5*(E(I)+E(I-1))*DX                                A 115
C     COMPUTE FUNCTIONS OF ELECTRIC FIELD                                   A 116
      IF (INSTEP .EQ.0) GO TO 198                                           A 117
      DO 195 I=1,MP1                                                        A 117A
      DE(I)=E(I)-ESAV(I)                                                    A 118
      JDISPL(I)=DIELK*EPSO*DE(I)/DT                                         A 119
195   DVXDT(I)=(VSUM(I)-VXSAV(I))/DT                                        A 120
C     ELECTRON VELOCITY-VM                                                  A 121
198   DO 230 I=1,MP1                                                        A 122
      AOP=E(I)/P                                                            A 123
      IF (MODVM.EQ.0) GO TO 200                                             A 124
      IF (AOP.LE.C7.OR.AOP.GE.C20) GO TO 200                                A 125
      VM0=C16+C17*AOP+C18*AOP*AOP+C19*AOP*AOP*AOP                           A 126
      GO TO 201                                                             A 127
200   VM0=E(I)/P*MUMF(E(I))                                                 A 128
201   IF (MODVNM.EQ.0) GO TO 205                                            A 129
      ADN=ABS(DN(I))                                                        A 130
      DM0=(ADN/NOM)**AVM                                                    A 131
      VM1=MUM0*AOP                                                          A 132
      IF (VM1.GT.VM1M) VM1=VM1M                                             A 133
      VM(I)=(VM1+(VM0-VM1)/(1.+DM0))*(300./TEM(I))**PWRM                    A 134
      GO TO 210                                                             A 135
```

Appendix A

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205   VM(I)=VM0*(300./TEM(I))**PWRM                                    A 136
C     HOLE VELOCITY-VP                                                 A 139
210   IF (MODVP.EQ.0) GO TO 220                                        A 140
      IF (AOP.LE.C3.OR.AOP.GE.C15) GO TO 220                           A 141
      VP0=C11+C12*AOP+C13*AOP*AOP+C14*AOP*AOP*AOP                      A 142
      GO TO 221                                                        A 143
220   VP0=MUPF(E(I))*E(I)/P                                            A 144
221   IF (MODVNP.EQ.0) GO TO 225                                       A 145
      DP0=(ADN/NOP)**AVP                                               A 146
      VP1=MUP0*AOP                                                     A 147
      IF (VP1.GT.VP1M) VP1=VP1M                                        A 148
      VP(I)=(VP1+(VP0-VP1)/(1.+DP0))*(300./TEM(I))**PWRP               A 149
      GO TO 230                                                        A 150
225   VP(I)=VP0*(300./TEM(I))**PWRP                                    A 151
230   CONTINUE                                                         A 151A
C     COMPUTE MAXIMUM VELOCITIES                                       A 152
      VMMAX=VM(1)                                                      A 152A
      VPMAX=VP(1)                                                      A 152B
      DO 235 I=1,MP1                                                   A 152C
      VMMAX=AMAX1(VMMAX,VM(I))                                         A 152D
235   VPMAX=AMAX1(VPMAX,VP(I))                                         A 152E
      VMAX=AMAX1(VPMAX,VMMAX)                                          A 152F
C     COMPUTE DIFFUSION CURRENT DENSITIES                              A 152G
      DO 255 I=1,MP1                                                   A 152H
      DNMDX(I)=(NM(I+1)-NM(I-1))/(2.*DX)                               A 152I
255   DNPDX(I)=(NP(I+1)-NP(I-1))/(2.*DX)                               A 152J
      DNMDX(1)=(NM(2)-NM(1))/DX                                        A 152K
      DNMDX(MP1)=(NM(MP1)-NM(M))/DX                                    A 152L
      DNPDX(1)=(NP(2)-NP(1))/DX                                        A 152M
      DNPDX(MP1)=(NP(MP1)-NP(M))/DX                                    A 152N
      DO 265 I=1,MP1                                                   A 152O
      AOP=E(I)/P                                                       A 152P
      DIFM(I)=0.                                                       A 152Q
      IF (AOP.NE.0.) DIFM(I)=BOLTZ*TEM(I)*VM(I)/AOP                    A 152R
      JMDIF(I)=-DIFM(I)*DNMDX(I)*EL                                    A 152S
      DIFP(I)=0.                                                       A 152T
      IF (AOP.NE.0.) DIFP(I)=BOLTZ*TEM(I)*VP(I)/AOP                    A 152U
265   JPDIF(I)=DIFP(I)*DNPDX(I)*EL                                     A 152V
C     CURRENT DENSITIES-JP,JM                                          A 152W
      DO 240 I=1,MP1                                                   A 153
      JP(I)=GP(I)*VP(I)                                                A 154
240   JM(I)=GM(I)*VM(I)                                                A 155
      JP(MP1)=JP(MP1)+JP0                                              A 155A
      GP(MP1)=ABS(JP(MP1)/VP(MP1))                                     A 155B
      NP(MP1)=GP(MP1)/EL                                               A 155C
      DENSIT=DENSMI                                                    A 156
      IF (EXTRAP.EQ.1) DENSIT=NM(1)                                    A 156A
C     COMPUTE INITIAL GAMMA                                            A 157
      IF (INSTEP.EQ.1) GO TO 245                                       A 157A
      IF (GAMMA.GE.0.) GO TO 243                                       A 157B
      GAMMA=0.                                                         A 157C
      DO 242 I=2,M                                                     A 157D
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242   GAMMA=GAMMA+JM(I)*UNIVD(E(I))                                          A 157E
      GAMMA=(GAMMA+(UNIVD(E(1))*JM(1)+UNIVD(E(MP1))*JM(MP1))/2.)*GAMSEC*     A 157F
     1DX                                                                     A 157G
243   IF (INSTEP.EQ.0) GO TO 250                                             A 157H
245   JM(1)=JM0+GAMI*JP(1)+GAMMA+DENSIT*EL*VM(1)                             A 158
      IF (EXTRAP.EQ.0) GO TO 250                                             A 159
      JM(1)=JM(1)+VM(1)*DT/DX*(2.*JM(1)-3.*JM(2)+JM(3))                      A 159A
250   GM(1)=ABS(JM(1)/VM(1))                                                 A 159B
      NM(1)=GM(1)/EL                                                         A 159C
C     COMPUTE AVERAGE CURRENT DENSITIES                                      A 160
      MJP=(JP(1)+JP(MP1))/2.                                                 A 160A
      MJM=(JM(1)+JM(MP1))/2.                                                 A 160B
      MJPDF=(JPDIF(1)+JPDIF(MP1))/2.                                         A 160C
      MJMDF=(JMDIF(1)+JMDIF(MP1))/2.                                         A 160D
      MJDSP=(JDISPL(1)+JDISPL(MP1))/2.                                       A 160E
      DO 400 I=2,M                                                           A 161F
      MJP=MJP+JP(I)                                                          A 160G
      MJM=MJM+JM(I)                                                          A 160H
      MJPDF=MJPDF+JPDIF(I)                                                   A 160I
      MJMDF=MJMDF+JMDIF(I)                                                   A 160J
400   MJDSP=MJDSP+JDISPL(I)                                                  A 160K
      MJP=MJP/FM                                                             A 160L
      MJM=MJM/FM                                                             A 160M
      MJPDF=MJPDF/FM                                                         A 161
      MJMDF=MJMDF/FM                                                         A 161A
      MJDSP=MJDSP/FM                                                         A 161B
      JC=MJP+MJM                                                             A 161C
      JDIF=MJMDF+MJPDF                                                       A 161D
      JINT=JC+JDIF+MJDSP                                                     A 161E
      IINT=ABS(S*JINT)                                                       A 161F
      IF(CIRCT(1).EQ.5) IEXT=(U-V)/R(1)                                      A 161G
      I23=ICUR(2)+ICUR(3)                                                    A 161H
      VNEW=V-RD*IINT-LD*DIDT
      IF (DT.EQ.0) DIDT=0.                                                   A 161I
      DDIDT=0.
      IF(DT.NE.0.) DIDT=(IINT-IINTO)/DT                                      A 161J
      IF(DT.NE.0.) DDIDT=(DIDT-DIDTO)/DT
      IF (MODT.EQ.0.) GO TO 30                                               A 161K
      DO 410 I=1,MP1                                                         A 162
      JDISSP(I)=JP(I)+JM(I)+JPDIF(I)+JMDIF(I)                                A 163
      DTEM(I)=JDISSP(I)*E(I)*DT/(DNSTY*SPCHT)                                A 164
410   TEM(I)=TEM(I)+DTEM(I)                                                  A 165
      MTEM=(TEM(1)+TEM(MP1))/2.                                              A 166
      DO 420 I=2,M                                                           A 167
420   MTEM=MTEM+TEM(I)                                                       A 168
      MTEM=MTEM/FM                                                           A 169
      DMTEM=0.                                                               A 169A
      DZT=DT*1.E9
      IF (DZT.NE.0.) DMTEM=(MTEM-TMPSAV)/DZT                                 A 169B
C     END OF COMPUTATION LOOP                                                A 169C
C     A52-91 INSERTED BETWEEN A169D AND 170                                  A 169D
C     TEST FOR STABILITY AND OTHER CRITERIA                                  A  52
30    CALL TEST(MINUS,INSTEP,CHECK,CHECK2,ISET,MSO)                          A  53
      GO TO (40,120,260), ISET                                               A  54
```

Appendix A

```
40    CHECK2=0                                                          A  55
      DO 45 I=1,MP1                                                     A  56
      ALPHA(I)=UNIVA(E(I))*(1.-CAT*(TEM(I)-300.))                       A  56A
45    BETA(I)=UNIVB(E(I))*(1.-CBT*(TEM(I)-300.))                        A  56B
C     TEST FOR PRINTING                                                 A  56C
      IF (MODP.EQ.2) GO TO 60                                           A  57
      IF (T.LT.(FLOAT(IT)*DTP+TPRINT(1))) GO TO 50                      A  58
      IT=IT+1                                                           A  59
      TIME(IT)=T                                                        A  60
      VOLT(IT)=V                                                        A  61
      CURR(IT)=IINT                                                     A  62
      JAVG(IT)=JC                                                       A  63
      CURR1(IT)=ICUR(1)                                                 A  64
      CURR2(IT)=ICUR(2)                                                 A  65
      CURR3(IT)=ICUR(3)                                                 A  66
      CLTT(IT)=DIDT
      TAVR(IT)=MTEM
50    IF (T.LT.TPRINT(INDEX)) GO TO 100                                 A  67
      GO TO 70                                                          A  68
60    IF (JINT.LT.TPRINT(INDEX)) GO TO 100                              A  69
C     CALCULATE VALUES TO BE PRINTED AND PRINT THEM                     A  70
C     (72 TO 76 REMOVED)                                                A  71
70    CALL OUTPUT(DVXDT)                                                A  77
      INDEX=INDEX+1                                                     A  78
      IF (INDEX.LE.IJ) GO TO 100                                        A  79
      WRITE (6,360)                                                     A  80
      WRITE (6,350) (VC(I),DVC(I),I=1,3)                                A  81
      IF(IEFCY.NE.1) GO TO 270                                          A  82
      CALL EFFCY                                                        A  83
      WRITE (6,500) AMP,AMPV,PJ,PV,PHASE,GNEG,RFP,AMPVDC,AMPJDC,        A  83A
     1DCPWR,EFF                                                         A  83B
      WRITE (6,501) AMP2,AMPV2,PJ2,PV2,PHASE2                           A  83C
      GO TO 270                                                         A  84
100   IF (CHECK.EQ.0) GO TO 110                                         A  85
      CHECK=0                                                           A  86
      MINUS=MINUS-1                                                     A  87
      IF (MINUS.GT.0) GO TO 110                                         A  88
      WRITE (6,310)                                                     A  89
260   WRITE (6,320)                                                     A  90
      CALL OUTPUT (DVXDT)                                               A  91
270   WRITE (6,330)                                                     A 170
      WRITE (6,340) (TIME(IK),VOLT(IK)-LD*CLTT(IK)-RD*CURR(IK),CURR(IK)
     1,JAVG(IK),CURR1(IK),CURR2(IK),VOLT(IK),TAVR(IK),IK=1,IPOINT)      A 172
275   READ (1,290) ENDING                                               A 174
      IF (ENDING.GE.10000) GO TO 280                                    A 175
      WRITE (6,300)                                                     A 176
      GO TO 10                                                          A 177
280   STOP                                                              A 178
C                                                                       A 179
C                                                                       A 180
290   FORMAT (I5)                                                       A 181
300   FORMAT (1H1)                                                      A 182
310   FORMAT (//51H THERE HAVE BEEN  MS  CASES OF NEGATIVE VELOCITIES./1 A 183
     16H END OF PROBLEM.)                                               A 184
```

```
320   FORMAT (47H PRINTOUT AT TIME OF ERROR FOLLOWS ON NEXT PAGE)          A 186
330   FORMAT (1H1,13X,1HT,14X,1HV,14X,1HI,11X,4HJAVG,13X,2HI1,13X,2HI2,    A 187
     18X,7HV(DLEG),7X,8HAVG.TEMP)                                          A 188
340   FORMAT (8(1PE15.6))                                                  A 189
350   FORMAT (1P,6E20.8)                                                   A 190
360   FORMAT (1H1,10X,46HCAPACITOR VOLTAGES AT LAST SUCCESSFUL PRINTOUT    A 191
     1//17X,3HVC1,16X,4HDVC1,17X,3HVC2,16X,4HDVC2,17X,3HVC3,16X,4HDVC3)    A 192
C     FORMAT (5E14.8)                                                      A 193
500   FORMAT (//47H THE AMPLITUDE OF THE FIRST HARMONIC OF JAVG IS,        A 194
     *1PE20.8/49H THE AMPLITUDE OF THE FIRST HARMONIC OF V(OLT) IS,        A 195
     *1PE20.8/54H THE PHASE OF THE FIRST HARMONIC OF JAVG IN DEGREES IS,   A 196
     *1PE20.8/51H THE PHASE OF THE FIRST HARMONIC OF V IN DEGREES IS,      A 197
     *1PE20.8/43H THE PHASE BETWEEN V AND JAVG IN DEGREES IS, 1PE20.8/     A 198
     *28H THE NEGATIVE CONDUCTANCE IS,1PE20.8/16H THE RF POWER IS,         A 199
     *1PE20.8/28H THE TIME AVERAGE VOLTAGE IS,1PE20.8/31H THE AVERAGE CU   A 200
     *RRENT DENSITY IS,1PE20.8/15H INPUT POWER IS,1PE20.8/18H THE EFFICI   A 201
     *ENCY IS,1PE20.8)                                                     A 202
501   FORMAT (//48H THE AMPLITUDE OF THE SECOND HARMONIC OF JAVG IS,       A 203
     *1PE20.8/50H THE AMPLITUDE OF THE SECOND HARMONIC OF V(OLT) IS,       A 204
     *1PE20.8/55H THE PHASE OF THE SECOND HARMONIC OF JAVG IN DEGREES IS   A 205
     *,1PE20.8/52H THE PHASE OF THE SECOND HARMONIC OF V IN DEGREES IS,    A 206
     *1PE20.8/43H THE PHASE BETWEEN V AND JAVG IN DEGREES IS,1PE20.8)      A 207
      END                                                                 A 208-
      SUBROUTINE INPUT(ENDING,CHECK1)                                     B   1
      INTEGER PRTFRQ,EXTRAP,ENDING,CHECK1                                 B   2
      DIMENSION TPRNTI(66), TINC(66), NINC(66)                            B   3
      REAL JPDIF,JMDIF,NP,NM,JP,JM,JDISPL,MJP;MJM,MJPDF,MJMDF,MJDSP       B   4
      REAL MUM,MUP,JMAX,JPO,JC,MTEM,  L,IINT,JINT,IINTO,ICUR,ICURO,IEXT,  B   5
     1I23,MUPO,NOP,MUMO,NOM,JMO                                           B   6
      COMMON /ABC/ MODA,MODB,MODD,MODVP,MODVM,MODVNP,MODVNM,MODT,A1,A2,   B   7
     1A3,A4,A5,A6,B1,B2,B3,B4,B5,B6,D1,D2,D3,D4,D5,D6,C1,C2,C3,C4,C5,C6,  B   8
     2C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,MUP,MUM,MUPO,  B   9
     3MUMO,AVP,AVM,NOP,NOM,VP1M,VM1M,CAT,CBT,PWRP,PWRM,TEMP               B  10
      COMMON /CIRT/ USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2,  B  11
     1RD,LD,R(3),L(3),C(3),CP,T1,IEFCY,VDD                                B  12
      COMMON /DSTR/ NP(201),NM(201),DN(201),TEM(201),E(201),DE(201),VSUM  B  13
     1(201),VP(201),VM(201),JP(201),JM(201),JPDIF(201),JMDIF(201),JDISPL  B  14
     2(201),RCMBR(201),ALPHA(201),BETA(201),TPRINT(201)                   B  15
      COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ,  B  16
     1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN  B  17
     2SPL,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC           B  18
      COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT,  B  19
     1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM,   B  20
     2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO      B  21
      READ (1,120)                                                        B  21A
      WRITE (6,120)                                                       B  22
      IF(ENDING.LE.3) GO TO 25                                            B  22A
      READ (1,150) MODA,A1,A2,A3,A4,A5                                    B  23
      READ (1,150) MODB,B1,B2,B3,B4,B5                                    B  24
      READ (1,150) MODD,D1,D2,D3,D4,D5                                    B  25
      READ (1,150) MODT,CAT,CBT,PWRM,PWRP,TEMP                            B  25A
      READ (1,130) DNSTY,SPCHT,THCND                                      B  25B
      READ (1,150) MODVP,MUP,C1,C2,C3,C4                                  B  26
      READ (1,150) MODVNP,MUPO,AVP,NOP,VP1M                               B  26A
```

Appendix A

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      READ (1,150) MODVM,MUM,C5,C6,C7,C8                                B  27
      READ (1,150) MODVNM,MUMO,AVM,NOM,VM1M                             B  27A
      READ (1,130) C9,C10,C15,C20                                       B  28
      READ (1,130) GAMSEC,TAUSEC,GAMMA,GAMI,JMO,JPO                     B  29
      READ (1,130) USTAT,DU,VO,OMEGA,T1,V                               B  30
      READ (1,500) V1,OMEGA1,PHI1,V2,OMEGA2,PHI2,IEFCY                  B  30A
      READ (1,130) P,D,S,T,DVDT,JMAX                                    B  31
      DO 10 ICIR=1,3                                                    B  32
10    READ (1,130) R(ICIR),L(ICIR),C(ICIR),VC(ICIR),DVC(ICIR),CP        B  33
      READ (1,113) RD,LD
      READ (1,140) STEPFA,DJMAXM,DIELK,DENSPL,DENSMI,DENS2,REC,EGAP     B  34
      READ (1,160) (NXPRNT(I),I=1,6)                                    B  35
      READ (1,160) M,PRTFRQ,N3S,MODP,MODFCH,EXTRAP,MS,IPOINT            B  36
      IF (N3S.GT.0) GO TO 20                                            B  37
      WRITE(6,400)                                                      B 38A
      CHECK1=1                                                          B 38B
      N3S=1                                                             B 38C
20    READ (1,170) (TPRNTI(I),TINC(I),NINC(I),I=1,N3S)                  B  39
      MP1=M+1                                                           B  40
      READ (1,180) (NP(I),I=1,MP1)                                      B  41
      READ (1,180) (NM(I),I=1,MP1)                                      B  42
      GO TO 27                                                          B  43
25    IF(ENDING.EQ.1.OR.ENDING.EQ.3) READ(1,130)USTAT,DU,VO,OMEGA,T1,V  B  43A
      IF(ENDING.EQ.2.OR.ENDING.EQ.3) READ(1,130) (R(ICIR),L(ICIR),C(ICIR B  43C
     *),VC(ICIR),DVC(ICIR),CP,ICIR=2,3)                                 B  43D
27    WRITE(6,210)                                                      B  43E
      WRITE (6,230) MODA,A1,A2,A3,A4,A5                                 B  44
      WRITE (6,220)                                                     B  45
      WRITE (6,230) MODB,B1,B2,B3,B4,B5                                 B  46
      WRITE (6,360)                                                     B  47
      WRITE (6,230) MODD,D1,D2,D3,D4,D5                                 B  48
      WRITE (6,225)                                                     B  48A
      WRITE (6,230) MODT,CAT,CBT,PWRM,PWRP,TEMP                         B  48B
      WRITE (6,235)                                                     B  49A
      WRITE (6,190) DNSTY,SPCHT,THCND                                   B  49B
      WRITE (6,370)                                                     B  49
      WRITE (6,230) MODVP,MUP,C1,C2,C3,C4                               B  50
      WRITE (6,375)                                                     B  50A
      WRITE (6,230) MODVNP,MUPO,AVP,NOP,VP1M                            B  50B
      WRITE (6,380)                                                     B  51
      WRITE (6,230) MODVM,MUM,C5,C6,C7,C8                               B  52
      WRITE (6,385)                                                     B  52A
      WRITE (6,230) MODVNM,MUMO,AVM,NOM,VM1M                            B  52B
      WRITE (6,390)                                                     B  53
      WRITE (6,190) C9,C10,C15,C20                                      B  54
      WRITE (6,240)                                                     B  55
      WRITE (6,200) GAMSEC,TAUSEC,GAMMA,GAMI,JMO,JPO                    B  56
      WRITE (6,250)                                                     B  57
      WRITE (6,200) USTAT,DU,VO,OMEGA,T1,V                              B  58
      WRITE (6,520)                                                     B  58A
      WRITE (6,510) V1,OMEGA1,PHI1,V2,OMEGA2,PHI2,IEFCY                 B  58B
      WRITE (6,260)                                                     B  59
      WRITE (6,200) P,D,S,T,DVDT,JMAX                                   B  60
      WRITE (6,270) CP                                                  B  61
      DO 30 ICIR=1,3                                                    B  62
```

```
30    WRITE (6,280) ICIR,R(ICIR),L(ICIR),C(ICIR),VC(ICIR),DVC(ICIR)      B  63
      WRITE (6,213) RD,LD
      WRITE (6,300)                                                      B  64
      WRITE (6,290) STEPFA,DJMAXM,DIELK,DENSPL,DENSMI,DENS2,REC,EGAP     B  65
      WRITE (6,310)
      WRITE (6,320) (NXPRNT(I),I=1,6)
      WRITE (6,330)                                                      B  66
      WRITE (6,340) M,PRTFRQ,N3S,MODP,MODFCH,EXTRAP,MS,IPOINT            B  67
      IF(ENDING.LE.3) GO TO 60                                           B  69A
      IF (MODFCH.LE.1) GO TO 40                                          B  70
      READ (1,180) (DN(I),I=1,MP1)                                       B  71
      GO TO 52                                                           B  72
40    DO 50 I=1,MP1                                                      B  73
50    DN(I)=0.0                                                          B  74
52    IF (MODT.LE.1) GO TO 55                                            B  74A
      READ (1,180) (TEM(I),I=1,MP1)                                      B  74B
      GO TO 60                                                           B  74C
55    MTEM=TEMP                                                          B  74D
      DO 57 I=1,MP1                                                      B  74E
57    TEM(I)=TEMP                                                        B  74F
C     CALCULATE AND PRINT TPRINT LIST                                    B  75
60    IF (MODP.EQ.1) GO TO 70                                            B  76
      IF (MODP.EQ.2) GO TO 90                                            B  77
      WRITE(6,410)                                                       B 78A
      CHECK1=1                                                           B 78B
      RETURN                                                             B 78C
C     TPRINT LIST FOR PRINTING ACCORDING TO TIME                         B  79
70    IJ=0                                                               B  80
      DO 80 J=1,N3S                                                      B  81
      NINK=NINC(J)                                                       B  82
      DO 80 I=1,NINK                                                     B  83
      IJ=IJ+1                                                            B  84
      XI=I-1                                                             B  85
80    TPRINT(IJ)=TPRNTI(J)+XI*TINC(J)                                    B  86
      GO TO 110                                                          B  87
C     TPRINT LIST FOR PRINTING ACCORDING TO CURRENT                      B  88
90    TPRINT(1)=0.0                                                      B  89
      IJ=1                                                               B  90
      DO 100 J=1,N3S                                                     B  91
      NINK=NINC(J)                                                       B  92
      DO 100 I=1,NINK                                                    B  93
      IJ=IJ+1                                                            B  94
100   TPRINT(IJ)=TPRNTI(J)*TINC(J)**(I-1)                                B  95
110   WRITE (6,350) IJ,(TPRINT(I),I=1,IJ)                               B  96
      RETURN                                                             B  97
C                                                                        B  98
113   FORMAT (2E13.7)
120   FORMAT (72H1IDENTIFICATION CARD HEADING EACH RUN                   B  99
     1                )                                                 B 100
130   FORMAT (6E13.7)                                                    B 101
140   FORMAT (8E10.3)                                                    B 102
150   FORMAT (I1,E13.7,4E14.7)                                           B 103
160   FORMAT (20I3)                                                      B 104
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```
170   FORMAT (2(2E14.8,I3,5X))                                          B 105
180   FORMAT (5E14.8)                                                   B 106
190   FORMAT (20X,1P,5E20.7)                                            B 107
200   FORMAT (1P,6E20.6)                                                B 108
210   FORMAT (/16X,4HMODA,18X,2HA1,18X,2HA2,18X,2HA3,18X,2HA4,18X,2HA5) B 109
213   FORMAT (11X,9HDIODE LEG,1P,2E20.6)
220   FORMAT (16X,4HMODB,18X,2HB1,18X,2HB2,18X,2HB3,18X,2HB4,18X,2HB5)  B 110
225   FORMAT (16X,4HMODT,17X,3HCAT,17X,3HCBT,16X,4HPWRM,16X,4HPWRP,14X,6 B 110A
     1HTEMP K)                                                          B 110B
230   FORMAT (I20,1P,5E20.7)                                            B 111
235   FORMAT (33X,7HDENSITY,13X,7HSPEC HT,12X,8HTHRM CND)               B 111A
240   FORMAT (14X,6HGAMSEC,14X,6HTAUSEC,15X,5HGAMMA,16X,4HGAMI,17X,3HJM0 B 112
     1,17X,3HJP0)                                                       B 112A
250   FORMAT (15X,5HUSTAT,18X,2HDU,18X,2HV0,15X,5HOMEGA,18X,2HT1,19X     B 113
     1,1HV)
260   FORMAT (19X,1HP,19X,1HD,19X,1HS,19X,1HT,16X,4HDVDT,16X,4HJMAX)     B 114
270   FORMAT (15X,27HCIRCUIT PARAMETERS WITH CP=,1P,E20.6/16X,4HICIR,19  B 115
     1X,1HR,19X,1HL,19X,1HC,18X,2HVC,17X,3HDVC)                         B 116
280   FORMAT (I20,1P,5E20.6)                                            B 117
290   FORMAT (1P,8E15.4)                                                B 118
300   FORMAT (9X,6HSTEPFA,9X,6HDJMAXM,10X,5HDIELK,9X,6HDENSPL,9X,6HDENSM B 119
     1I,10X,5HDENS2,12X,3HREC,11X,4HEGAP)                               B 120
310   FORMAT (4X,6HNXPRNT)                                              B 121
320   FORMAT (2013)                                                     B 122
330   FORMAT (11X,1HM,6X,6HPRTFRQ,9X,3HN3S,8X,4HMODP,6X,6HMODFCH,6X,     B 123
     16HEXTRAP,10X,2HMS,6X,6HIPOINT)                                    B 124
340   FORMAT (9I12)                                                     B 125
350   FORMAT (12H TPRINT LIST,I10,9H   VALUES/(1P,8E15.5))              B 126
360   FORMAT (16X,4HMODD,18X,2HD1,18X,2HD2,18X,2HD3,18X,2HD4,18X,2HD5)  B 127
370   FORMAT (15X,5HMODVP,17X,3HMUP,18X,2HC1,18X,2HC2,18X,2HC3,18X,     B 128
     12HC4)
375   FORMAT (14X,6HMODVNP,16X,4HMUP0,17X,3HAVP,17X,3HNOP,16X,4HVP1M)   B 128A
380   FORMAT (15X,5HMODVM,17X,3HMUM,18X,2HC5,18X,2HC6,18X,2HC7,18X,      B 129
     12HC8)
385   FORMAT (14X,6HMODVNM,16X,4HMUM0,17X,3HAVM,17X,3HNOM,16X,4HVM1M)   B 129A
390   FORMAT (38X,2HC9,17X,3HC10,17X,3HC15,17X,3HC20)                   B 130
400   FORMAT (75H  N3S (NO. OF TPRINT TRIPLES) IS NOT POSITIVE AS REQUIR B 131
     1ED.  END OF PROBLEM.)                                             B 132
410   FORMAT (57H MODP IS NOT EQUAL TO 1 OR 2 AS REQUIRED.  END OF PROBL B 133
     1EM)                                                               B 134
500   FORMAT(6E13.7,I2)                                                 B 135
510   FORMAT(1P,6E20.6,I10)                                             B 136
520   FORMAT(18X,2HV1,14X,6HOMEGA1,16X,4HPHI1,18X,2HV2,14X,6HOMEGA2,16X, B 137
     *4HPHI2,5X,5HIFOUR)                                                B 138
      END                                                               B 139-
      SUBROUTINE INCON(CIRCT,ENDING)                                    C   1
      REAL MUM,MUP,NP,NM,JP,JC,JP0,JM0,JM ,IINT,IINTO,IEXT,JINT,JMAX,I23 C   2
     1,ICUR,ICURO,L,JPDIF,JMDIF,JDISPL,MJP,MJM,MJPDF,MJMDF,MJDSP,MTEM,  C   3
     2MUM0,MUP0,NOM,NOP                                                 C   4
      INTEGER CIRCT(10),ENDING                                          C   5
      DIMENSION ONP(101),ONM(101)                                       C   6
      COMMON /ABC/ MODA,MODB,MODD,MODVP,MODVM,MODVNP,MODVNM,MODT,A1,A2, C   7
     1A3,A4,A5,A6,B1,B2,B3,B4,B5,B6,D1,D2,D3,D4,D5,D6,C1,C2,C3,C4,C5,C6, C   8
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     2C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,MUP,MUM,MUPO,  C   9
     3MUMO,AVP,AVM,NOP,NOM,VP1M,VM1M,CAT,CBT,PWRP,PWRM,TEMP              C  10
      COMMON /CIRT/ USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2,  C  11
     1RD,LD,R(3),L(3),C(3),CP,T1,IEFCY,VDD                               C  12
      COMMON /DSTR/ NP(201),NM(201),DN(201),TEM(201),E(201),DE(201),VSUM  C  13
     1(201),VP(201),VM(201),JP(201),JM(201),JPDIF(201),JMDIF(201),JDISPL  C  14
     2(201),RCMBR(201),ALPHA(201),BETA(201),TPRINT(201)                   C  15
      COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ,  C  16
     1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN  C  17
     2SPI.,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC          C  18
      COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT,  C  19
     1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM,   C  20
     2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO      C  21
      IF(ENDING.GT.3) GO TO 6                                            C  23
      DO 5 I=1,MP1                                                       C  23A
      NP(I)=ONP(I)                                                       C  23B
5     NM(I)=ONM(I)                                                       C  23C
      T=OT                                                               C  23O
      DVDT=ODVDT                                                         C  23P
      VC(1)=OVC1                                                         C  23Q
      DVC(1)=ODVC1                                                       C  23R
      GO TO 55                                                           C  23U
6     EL=1.6022E-19                                                      C  23V
      EPSO=8.854E-14                                                     C  24
      FM=M                                                               C  25
      DX=D/FM                                                            C  26
      A6=ABD(MODA,A1,A2,A3,A5)                                           C  27
      B6=ABD(MODB,B1,B2,B3,B5)                                           C  28
      D6=ABD(MODD,D1,D2,D3,D5)                                           C  29
      IF (MODVP.EQ.0) C9=SQRT(C3)**3-C3**2/C2*MUP*(1.-C1*C3)             C  30
      IF (MODVM.EQ.0) C10=SQRT(C7)**3-C7**2/C6*MUM*(1.-C5*C7)            C  31
      WRITE (6,270)                                                      C  32
      WRITE (6,280) A6,B6,D6,C9,C10                                      C  33
C     DETERMINE TYPE OF SERIES CIRCUIT                                   C  34
      DO 50 ICIR=1,3                                                     C  35
      IF (L(ICIR).EQ.0.) GO TO 20                                        C  36
      IF (C(ICIR).GE.1.E20) GO TO 10                                     C  37
C     LC OR LCR CIRCUIT                                                  C  38
      CIRCT(ICIR)=3                                                      C  39
      GO TO 50                                                           C  40
C     LR OR L CIRCUIT                                                    C  41
10    CIRCT(ICIR)=4                                                      C  42
      GO TO 50                                                           C  43
20    IF (C(ICIR).LT.1.E20) GO TO 30                                     C  44
      IF (R(ICIR).NE.0.) GO TO 40                                        C  45
C     OPEN CIRCUIT                                                       C  46
      CIRCT(ICIR)=1                                                      C  47
      GO TO 50                                                           C  48
C     RC CIRCUIT                                                         C  49
30    CIRCT(ICIR)=2                                                      C  50
      GO TO 50                                                           C  51
C     R CIRCUIT                                                          C  52
40    CIRCT(ICIR)=5                                                      C  53
50    CONTINUE                                                           C  54
```

Appendix A

```
C     COMPUTE CIRCUIT CONSTANTS                                                C  55
55    DO 80 ICIR=1,3                                                           C  56
      IF (R(ICIR)*C(ICIR).EQ.0.) GO TO 60                                      C  57
      CST(1,ICIR)=1./(R(ICIR)*C(ICIR))                                         C  58
60    IF (L(ICIR)*C(ICIR).EQ.0.) GO TO 70                                      C  59
      CST(2,ICIR)=1./(L(ICIR)*C(ICIR))                                         C  60
70    IF (L(ICIR).EQ.0.) GO TO 80                                              C  61
      CST(3,ICIR)=R(ICIR)/L(ICIR)                                              C  62
80    CONTINUE                                                                 C  63
      CST(4,1)=S*EPSO*DIELK/D                                                  C  64
      CST(5,1)=1./(CP+CST(4,1))                                                C  65
      CST(6,1)=DX/(2.*EPSO*DIELK)                                              C  66
      CST(7,1)=EL*CST(6,1)                                                     C  67
      IF(ENDING.LE.3) GO TO 90                                                 C  67A
      IF (MODVP.EQ.1) CALL TESTSQ (C1,C2,C3,C9,C15,MUP,C11,C12,C13,C14)        C  68
      IF (MODVM.EQ.1) CALL TESTSQ (C5,C6,C7,C10,C20,MUM,C16,C17,C18,C19)       C  69
      WRITE (6,290) C11,C12,C13,C14,C16,C17,C18,C19                            C  70
C     PRINT INITIAL DENSITIES AND TEMPERATURE                                  C  71
90    WRITE (6,250) T,V                                                        C  83
      DO 110 I=1,MP1                                                           C  84
      J=I-1                                                                    C  85
110   WRITE (6,260) J,NP(I),NM(I),DN(I),TEM(I)                                 C  86
C     COMPUTE U                                                                C 105
      U=USTAT                                                                  C 106
      IF (T.LT.T1) GO TO 140                                                   C 107
      IF (IEFCY.EQ.0) GO TO 130                                                C 108
      U=U+DU+V0*COS(OMEGA*T)+V1*COS(OMEGA1*T+PHI1)+V2*COS(OMEGA2*T+PHI2)       C 109
      GO TO 140                                                                C 110
130   U=U+DU+V0*SIN(OMEGA*T)                                                   C 111
140   DO 150 I=1,MP1                                                           C 112
150   JDISPL(I)=DIELK*EPSO*DVDT/D                                              C 113
C     STORE INITIAL CONDITIONS                                                 C 115
      DO 220 ICIR=1,3                                                          C 117
      DVCO(ICIR)=DVC(ICIR)                                                     C 118
      VCO(ICIR)=VC(ICIR)                                                       C 119
      VS=V                                                                     C 120
      IF (ICIR.EQ.1) VS=U-V                                                    C 121
      ICIRT=CIRCT(ICIR)                                                        C 122
      GO TO (190,200,200,190,210), ICIRT                                       C 123
190   ICUR(ICIR)=VC(ICIR)                                                      C 124
      GO TO 220                                                                C 125
200   ICUR(ICIR)=C(ICIR)*DVC(ICIR)                                             C 126
      GO TO 220                                                                C 127
210   ICUR(ICIR)=VS/R(ICIR)                                                    C 128
220   ICURO(ICIR)=ICUR(ICIR)                                                   C 129
      IEXT=ICUR(1)                                                             C 131
      DIDT=0                                                                   C 133
      DDIDT=0
      I23=ICUR(2)+ICUR(3)                                                      C 134
      IF(ENDING.LE.3) RETURN                                                   C 134A
      DO 230 I=1,MP1                                                           C 142
      ONP(I)=NP(I)                                                             C 143
230   ONM(I)=NM(I)                                                             C 144
      OT=T                                                                     C 156
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      ODVDT=DVDT                                                        C 157
      OVC1=VC(1)                                                        C 158
      ODVC1=DVC(1)                                                      C 159
      RETURN                                                            C 162
250   FORMAT (3H1T=,1PE16.6,5H   V=,E16.6//4X,1HM,18X,2HN+,18X,2HN-,18X, C 163
     12HDN,14X,6HTEMP K)                                                C 164
260   FORMAT (I5,1P,4E20.6)                                             C 165
270   FORMAT (/38X,2HA6,18X,2HB6,18X,2HD6,18X,2HC9,17X,3HC10)           C 166
280   FORMAT (20X,1P,5E20.6)                                            C 167
290   FORMAT (37X,3HC11,17X,3HC12,17X,3HC13,17X,3HC14/20X,1P,4E20.7/37X, C 168
     13HC16,17X,3HC17,17X,3HC18,17X,3HC19/20X,4E20.7)                   C 169
      END                                                               C 170-
      SUBROUTINE EXTCIR (ISET,CIRCT)                                    D   1
      REAL JC,IINT,JINT,IINTO, MJDSP,IEXT,L,ICUR,ICURO,I23,JMAX,JMO,JPO D   2
      COMMON /CIRT/ USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2, D   3
     1RD,LD,R(3),L(3),C(3),CP,T1,IEFCY,VDD                              D   4
      COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ, D   5
     1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN D   6
     2SPL,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC         D   7
      COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT, D   8
     1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM, D   9
     2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO    D  10
      REAL MJM,MJP,MJMDF,MJPDF,MTEM                                     D  11
      INTEGER CIRCT(10)                                                 D  12
      IF (ISET.EQ.2) GO TO 20                                           D  13
C     UPDATE QUANTITIES                                                 D  14
      IINTO=IINT                                                        D  15
      DIDTO=DIDT
      DO 10 ICIR=1,3                                                    D  16
      DVCO(ICIR)=DVC(ICIR)                                              D  17
      VCO(ICIR)=VC(ICIR)                                                D  18
10    ICURO(ICIR)=ICUR(ICIR)                                            D  19
C     COMPUTE CURRENT IN SERIES CIRCUITS                                D  25
20    DO 90 ICIR = 1,3                                                  D  26
      VS=V                                                              D  27
      IF (ICIR.EQ.1) VS=U-V                                             D  28
      ICIRT=CIRCT(ICIR)                                                 D  29
      GO TO (40,50,60,70,80), ICIRT                                     D  30
40    ICUR(ICIR)=0                                                      D  31
      GO TO 90                                                          D  32
50    DVC(ICIR)=CST(1,ICIR)*(VS-VC(ICIR))                               D  33
      ICUR(ICIR)=C(ICIR)*DVC(ICIR)                                      D  34
      GO TO 90                                                          D  35
60    DVC2=CST(2,ICIR)*(VS-VC(ICIR))-CST(3,ICIR)*DVC(ICIR)              D  36
      DVC(ICIR)=DVCO(ICIR)+DT*DVC2                                      D  37
      ICUR(ICIR)=C(ICIR)*DVC(ICIR)                                      D  38
      GO TO 90                                                          D  39
70    DI=(1./L(ICIR))*VS-CST(3,ICIR)*ICURO(ICIR)                        D  40
      ICUR(ICIR)=ICURO(ICIR)+DT*DI                                      D  41
      GO TO 90                                                          D  42
80    ICUR(ICIR)=VS/R(ICIR)                                             D  43
90    VC(ICIR)=VCO(ICIR)+DT*DVC(ICIR)                                   D  44
C     COMPUTE VOLTAGE AND CURRENT OF DEVICE                             D  45
```

Appendix A

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      DVDT=(ICUR(1)-ICUR(2)-ICUR(3)-IINT)/CP                              D  46
      V=V+DT*DVDT                                                         D  47
      IEXT=ICUR(1)                                                        D  48
      RETURN                                                              D  53
      END                                                                 D  54-
      SUBROUTINE TEST(MINUS,INSTEP,CHECK,CHECK2,ISET,MSO)                 E   1
      REAL NMSAV,NPSAV,JC,MJDSP, JMAX,  IINT,JINT,IINTO,I23,ICUR,ICURO,   E   2
     *IEXT,NP,NM,JP,JM,JCSAV,JDISPL,JMDIF,JPDIF,MJP,MJM,MJPDF,MJMDF       E   3
      INTEGER  CHECK,CHECK2                                               E   4
      COMMON /DSTR/ NP(201),NM(201),DN(201),TEM(201),E(201),DE(201),VSUM  E   5
     1(201),VP(201),VM(201),JP(201),JM(201),JPDIF(201),JMDIF(201),JDISPL  E   6
     2(201),RCMBR(201),ALPHA(201),BETA(201),TPRINT(201)                   E   7
      COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ,  E   8
     1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN  E   9
     2SPL,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC           E  10
      COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT,  E  11
     1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM,   E  12
     2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO      E  13
      COMMON /SAV/ NPSAV(201),NMSAV(201),ESAV(201),VXSAV(201),VPSAV(201)  E  14
     1,VMSAV(201),JPSAV(201),JMSAV(201),VSAV,TSAV,JCSAV,GAMSAV,TMPSAV     E  15
      REAL JMSAV,JPSAV,JMO,JPO,MTEM                                       E  17
      IF (INSTEP.NE.0) GO TO 60                                           E  22
C     STORE PRESENT VALUE OF VARIABLES                                    E  37
20    DO 50 I=1,MP1                                                       E  38
      NPSAV(I)=NP(I)                                                      E  39
      NMSAV(I)=NM(I)                                                      E  40
      VPSAV(I)=VP(I)                                                      E  41
      VMSAV(I)=VM(I)                                                      E  42
      JPSAV(I)=JP(I)                                                      E  43
      JMSAV(I)=JM(I)                                                      E  44
      VXSAV(I)=VSUM(I)                                                    E  47
50    ESAV(I)=E(I)                                                        E  48
      TSAV=T                                                              E  49
      VSAV=V                                                              E  51
      GAMSAV=GAMMA                                                        E  52
      JCSAV=JC                                                            E  52A
      TMPSAV=MTEM                                                         E  52B
      ISET=1                                                              E  53
      IF (CHECK.EQ.0) MINUS=MSO                                           E  54
      GO TO 150                                                           E  55
C     CHECK FOR NEGATIVE VELOCITIES                                       E  56
60    DO 70 I=1,MP1                                                       E  57
      IF (VM(I).LT.0..OR.VP(I).LT.0.) GO TO 80                            E  58
70    CONTINUE                                                            E  59
      GO TO 90                                                            E  60
80    CONTINUE                                                            E  61
      CHECK=1                                                             E  62
C     CHECK FOR LARGE CURRENT OR TIME                                     E  63
90    IF (MODP.EQ.2) GO TO 100                                            E  64
      IF (ABS(JC).LE.JMAX) GO TO 110                                      E  65
C     CURRENT DENSITY TOO LARGE                                           E  67
      WRITE (6,160)                                                       E  67A
      GO TO 140                                                           E  68
```

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100   IF (T.LE.JMAX) GO TO 110                                          E  69
      WRITE (6,170)                                                     E  70
      GO TO 140                                                         E  71
C     CHECK FOR TOO RAPID CURRENT CHANGE                                E  72
110   DJC=ABS((JC-JCSAV)/JC)                                            E  73
      IF (DJC.LE.DJMAXM) GO TO 20                                       E  73A
      WRITE (6,180)                                                     E  73B
      WRITE (6,190) T,JC,JCSAV,DJC                                      E  73C
      MINUS=MSO                                                         E  74
      CHECK=0                                                           E  75
      CHECK2=CHECK2+1                                                   E  77
      IF (CHECK2.LE.2) GO TO 120                                        E  78
      GO TO 140                                                         E  80
C     RESET ARRAYS TO SAVE VALUES AND REPEAT INSTEP                     E  81
120   DO 130 I=1,MP1                                                    E  82
      NP(I)=NPSAV(I)                                                    E  83
      NM(I)=NMSAV(I)                                                    E  84
      VP(I)=VPSAV(I)                                                    E  85
      VM(I)=VMSAV(I)                                                    E  86
      JP(I)=JPSAV(I)                                                    E  87
      JM(I)=JMSAV(I)                                                    E  88
      VSUM(I)=VXSAV(I)                                                  E  91
130   E(I)=ESAV(I)                                                      E  92
      T=TSAV                                                            E  93
      V=VSAV                                                            E  95
      GAMMA=GAMSAV                                                      E  96
      JC=JCSAV                                                          E  96A
      MTEM=TMPSAV                                                       E  96B
      ISET=2                                                            E  97
      GO TO 150                                                         E  98
140   ISET=3                                                            E  99
150   RETURN                                                            E 100
160   FORMAT (/29H CURRENT DENSITY EXCEEDS JMAX)                        E 101
170   FORMAT (/18H TIME EXCEEDS JMAX)                                   E 102
180   FORMAT (/33H TIME STEP REDUCED,T,JC,JCSAV,DJC)                    E 103
190   FORMAT (1P,4E20.7)                                                E 103A
      END                                                               E 104-
      SUBROUTINE OUTPUT(DVXDT)                                          F   1
      REAL MJP,MJM,JDIF,MJDSP,IEXT,IINT,JINT,I23,L,IINTO,JMO,JPO,JC,JP,  F   2
     1JM,JMAX,ICUR,ICURO,MJMDF,MJPDF,JPDIF,JMDIF,JDISPL,NP,NM,MTEM      F   3
      INTEGER PRTFRQ                                                    F   4
      DOUBLE PRECISION TITLE(40)
      DIMENSION XPR(6),DVXDT(101)
      COMMON /DSTR/ NP(201),NM(201),DN(201),TEM(201),E(201),DE(201),VSUM F   6
     1(201),VP(201),VM(201),JP(201),JM(201),JPDIF(201),JMDIF(201),JDISPL F   7
     2(201),RCMBR(201),ALPHA(201),BETA(201),TPRINT(201)                 F   8
      COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ, F   9
     1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN F  10
     2SPL,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC         F  11
      COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT, F  12
     1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM, F  13
     2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO     F  14
      COMMON /CIRT/ USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2, F  15
```

Appendix A

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     1RD,LD,R(3),L(3),C(3),CP,T1,IEFCY,VNEW                                F  16
      DATA TITLE             /6H     A,4HLPHA,6H       ,4HBETA,6H     D,4H  F  20
     1ELTA,6H     V,4H-(X),6H     V,4H+(X),6H  ALPH,4HA*J-,6H   BET,4HA*   F  21
     2J+,6H     N,4HET Q,6HRECOM ,4HRATE,6H  J+(D,4HIFF),6H  J-(D,4HIFF)   F  22
     3,6H   J D,4HISPL,6H   J T,4HOTAL,6H       ,4HV(X),6H  DV(X,4H)/DT,6   F  23
     4H     N,4H+(X),6H     N,4H-(X),6H     J,4H+(X),6H     J,4H-(X),6H    F  24
     5   TE,4HMP K/                                                        F  24A
      UNIVD(EA)=UNIV(P,MODD,EA,D1,D2,D3,D4,D5,D6)                          F  25
C     COMPUTE MEAN VALUES                                                  F  26
      BJPDX=(BETA(1)*JP(1)+BETA(MP1)*JP(MP1))/2.                          F  29
      AJMDX=(ALPHA(1)*JM(1)+ALPHA(MP1)*JM(MP1))/2.                        F  30
      BETDX=(BETA(1)+BETA(MP1))/2.                                        F  31
      ALPDX=(ALPHA(1)+ALPHA(MP1))/2.                                      F  32
      RCMBAV=(RCMBR(1)+RCMBR(MP1))/2.                                     F  33
      DO 10 I=2,M                                                         F  34
      RCMBAV=RCMBAV+RCMBR(I)                                              F  35
      ALPDX=ALPDX+ALPHA(I)                                                F  36
      BETDX=BETDX+BETA(I)                                                 F  37
      AJMDX=AJMDX+ALPHA(I)*JM(I)                                          F  38
10    BJPDX=BJPDX+BETA(I)*JP(I)                                           F  39
      ALPDX=ALPDX*DX                                                      F  42
      BETDX=BETDX*DX                                                      F  43
      AJMDX=AJMDX/FM                                                      F  44
      RCMBAV=RCMBAV/FM                                                    F  45
      BJPDX=BJPDX/FM                                                      F  48
      JDIF=MJPDF+MJMDF                                                    F  49
      I1=2*NXPRNT(1)-1                                                    F  53
      I2=2*NXPRNT(2)-1                                                    F  54
      I3=2*NXPRNT(3)-1                                                    F  55
      I4=2*NXPRNT(4)-1                                                    F  56
      I5=2*NXPRNT(5)-1                                                    F  57
      I6=2*NXPRNT(6)-1                                                    F  57A
      WRITE (6,240) T,VNEW,U,MJP,MJM, JC  ,V,DT,VPMAX,VMMAX,IEXT,IINT,J   F  58
     1INT,DVDT,ALPDX,AJMDX,BETDX,BJPDX,RCMBAV,I23,DIDT,MJPDF,MJMDF,JDIF,  F  59
     2MJDSP,MTEM,DMTEM,DENS2T,TITLE(I1                                    F  60
     3),TITLE(I1+1),TITLE(I2),TITLE(I2+1),TITLE(I3),TITLE(I3+1),TITLE(I4  F  61
     4),TITLE(I4+1),TITLE(I5),TITLE(I5+1),TITLE(I6),TITLE(I6+1)           F  61A
      VSUM(1)=0.                                                          F  62
      XPRT=0.                                                             F  63
      XMPLY=PRTFRQ                                                        F  64
      DO 230 I=1,MP1,PRTFRQ                                               F  65
      DO 220 J=1,6                                                        F  66
      NJ=NXPRNT(J)                                                        F  67
      GO TO (30,40,50,60,70,80,90,100,110,120,130,140,150,160,170,180,19  F  68
     10,200,210,215), NJ                                                  F  69
30    XPRINT=ALPHA(I)                                                     F  70
      GO TO 220                                                           F  71
40    XPRINT=BETA(I)                                                      F  72
      GO TO 220                                                           F  73
50    XPRINT=UNIVD(E(I))                                                  F  74
      GO TO 220                                                           F  75
60    XPRINT=VM(I)                                                        F  76
      GO TO 220                                                           F  77
```

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70    XPRINT=VP(I)                                                    F  78
      GO TO 220                                                       F  79
80    XPRINT=ALPHA(I)*JM(I)                                           F  80
      GO TO 220                                                       F  81
90    XPRINT=BETA(I)*JP(I)                                            F  82
      GO TO 220                                                       F  83
100   XPRINT=NP(I)-NM(I)+DN(I)                                        F  84
      GO TO 220                                                       F  85
110   XPRINT=RCMBR(I)                                                 F  88
      GO TO 220                                                       F  89
120   XPRINT=JPDIF(I)                                                 F  90
      GO TO 220                                                       F  91
130   XPRINT=JMDIF(I)                                                 F  92
      GO TO 220                                                       F  93
140   XPRINT=JDISPL(I)                                                F  94
      GO TO 220                                                       F  95
150   XPRINT=JP(I)+JM(I)+JDISPL(I)+JPDIF(I)+JMDIF(I)                  F  96
      GO TO 220                                                       F  97
160   XPRINT=VSUM(I)                                                  F  98
      GO TO 220                                                       F  99
170   XPRINT=DVXDT(I)                                                 F 100
      GO TO 220                                                       F 101
180   XPRINT=NP(I)                                                    F 102
      GO TO 220                                                       F 103
190   XPRINT=NM(I)                                                    F 104
      GO TO 220                                                       F 105
200   XPRINT=JP(I)                                                    F 106
      GO TO 220                                                       F 107
210   XPRINT=JM(I)                                                    F 108
      GO TO 220                                                       F 108A
215   XPRINT=TEM(I)                                                   F 108B
220   XPR(J)=XPRINT                                                   F 109
      WRITE (6,250) XPRT,E(I),(XPR(J),J=1,6)                          F 110
230   XPRT=XPRT+XMPLY*DX                                              F 111
      RETURN                                                          F 112
C                                                                     F 113
240   FORMAT (1H1,14X,1HT,12X,4HVNEW,15X,1HU,11X,5HJ+AVG,11X,5HJ-AVG,11  F 114
     1X,5HJ AVG,13X,1HV/1P7E16.6/14X,2HDT,11X,5HV+MAX,11X,5HV-MAX,11X,5  F 115
     2HI EXT,11X,5HI INT,11X,5HJ INT,11X,5HDV/DT/7E16.6/6X,10HD*ALPHAAVG  F 116
     3,9X,7HA*J-AVG,7X,9HD*BETAAVG,9X,7HB*J+AVG,5X,11HRECOMRATAVG,10X,    F 117
     46H  I23,11X,5HDI/DT/1P,7E16.6/11X,5HJ+DIF,11X,5HJ-DIF,11X,          F 118
     55HJ DIF,9X,7HJ DISPL,6X,10HAVE TEMP K,8X,8HTEM RATE,10X,            F 119
     66HDENS2T/1P,7E16.6/9X,1HX,13X,4HE(X)
     7,6(7X,A6,A4))
250   FORMAT (2X,1PE10.3,1P,7E17.5)                                   F 121
      END                                                             F 122-
      FUNCTION ABD (MOD,H1,H2,H3,H4)                                  H   1
C     A6 CALLS     ABD(MODA,A1,A2,A3,A5)                              H   2
C     B6 CALLS     ABD(MODB,B1,B2,B3,B5)                              H   3
C     D6 CALLS     ABD(MODD,D1,D2,D3,D5)                              H   4
      ABC=0.                                                          H   5
      IF (H4.EQ.0..OR.MOD.EQ.0) GO TO 10                              H   6
      IF (MOD.EQ.2) H4=SQRT(H4)                                       H   7
      ABC=-H4*(ALOG(H1/H3)-H2/H4)                                     H   8
```

Appendix A

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10    ABD=ABC                                                    H   9
      RETURN                                                     H  10
      END                                                        H  11-
      FUNCTION UNIV (XP,MOD,EA,G1,G2,G3,G4,G5,G6)                I   1
C     UNIVA(EA) = UNIV(XP,MODA,EA,A1,A2,A3,A4,A5,A6)             I   2
C     UNIVB(EA) = UNIV(XP,MODB,EA,B1,B2,B3,B4,B5,B6)             I   3
C     UNIVD(EA) = UNIV(XP,MODD,EA,D1,D2,D3,D4,D5,D6)             I   4
      VAR1(F1,F2)=XP*F1*EXP(-F2*(XP/EB)**XPON)                   I   5
      VAR=0.                                                     I   6
      IF (MOD.EQ.0) GO TO 70                                     I   7
      EB=ABS(EA)                                                 I   8
      EAP=EB/XP                                                  I   9
      IF (EAP.LE.G2/100.) GO TO 70                               I  10
      XPON=1.                                                    I  11
      GO TO (10,40,50,60), MOD                                   I  12
10    IF (EAP.GT.G5) GO TO 30                                    I  13
20    VAR=VAR1(G1,G2)                                            I  14
      GO TO 70                                                   I  15
30    VAR=VAR1(G3,G6)                                            I  16
      GO TO 70                                                   I  17
40    XPON=.5                                                    I  18
      IF (EAP.GT.G5) GO TO 30                                    I  19
      GO TO 20                                                   I  20
50    VAR=VAR1(G1,G2)+VAR1(G3,G4)                                I  21
      GO TO 70                                                   I  22
60    XPON=.5                                                    I  23
      GO TO 50                                                   I  24
70    UNIV=VAR                                                   I  25
      RETURN                                                     I  26
      END                                                        I  27-
      REAL FUNCTION MUF(Z,P,G1,G2,G3,G4,G5,MU)                   J   1
C     MUPF(Z) CALLS     MUF(Z,P,C1,C2,C3,C4,C9,MUP)              J   2
C     MUMF(Z) CALLS     MUF(Z,P,C5,C6,C7,C8,C10,MUM)             J   3
      REAL MU                                                    J   4
      Y=ABS(Z)                                                   J   5
      IF (Y.GT.G3*P.AND.Y.NE.0) GO TO 10                         J   6
      MUF=MU*(1.-G1*Y/P)                                         J   7
      RETURN                                                     J   9
10    Y=SQRT(1./Y)                                               J  10
      MUF=G2*Y*(1.-G5*Y**3)                                      J  11
20    IF (MUF.GT.G4*Y**2) MUF=G4*Y**2                            J  12
      RETURN                                                     J  13
      END                                                        J  14-
      SUBROUTINE TESTSQ (D1,D2,D3,D4,D5,D6,E1,E2,E3,E4)          K   1
      DIMENSION A(4,4), B(4)                                     K   2
      A(1,1)=1.                                                  K   3
      A(1,2)=D3                                                  K   4
      A(1,3)=D3*D3                                               K   5
      A(1,4)=D3*D3*D3                                            K   6
      A(2,1)=1.                                                  K   7
      A(2,2)=D5                                                  K   8
      A(2,3)=D5*D5                                               K   9
      A(2,4)=D5*D5*D5                                            K  10
```

```
      A(3,1)=0.                                                    K  11
      A(3,2)=1.                                                    K  12
      A(3,3)=2.*D3                                                 K  13
      A(3,4)=3.*D3*D3                                              K  14
      A(4,1)=0.                                                    K  15
      A(4,2)=1.                                                    K  16
      A(4,3)=2.*D5                                                 K  17
      A(4,4)=3.*D5*D5                                              K  18
      B(1)=D6*D3*(1.-D1*D3)                                        K  19
      B(2)=D2*(SQRT(D5)-D4/D5)                                     K  20
      B(3)=D6*(1.-2.*D1*D3)                                        K  21
      B(4)=D2*(1./(2.*SQRT(D5))+D4/(D5*D5))                        K  22
      CALL SIMQ (A,B,4,KS)                                         K  23
      E1=B(1)                                                      K  24
      E2=B(2)                                                      K  25
      E3=B(3)                                                      K  26
      E4=B(4)                                                      K  27
      RETURN                                                       K  28
      END                                                          K  29-
      SUBROUTINE SIMQ(A,B,N,KS)                                    L  48
      DIMENSION A(1), B(1)                                         L  49
C                                                                  L  50
C        FORWARD SOLUTION                                          L  51
C                                                                  L  52
      TOL=0.0                                                      L  53
      KS=0                                                         L  54
      JJ=-N                                                        L  55
      DO 80 J=1,N                                                  L  56
      JY=J+1                                                       L  57
      JJ=JJ+N+1                                                    L  58
      BIGA=0                                                       L  59
      IT=JJ-J                                                      L  60
      DO 20 I=J,N                                                  L  61
C                                                                  L  62
C        SEARCH FOR MAXIMUM COEFFICIENT IN COLUMN                  L  63
C                                                                  L  64
      IJ=IT+I                                                      L  65
      IF (ABS(BIGA)-ABS(A(IJ))) 10,20,20                           L  66
10    BIGA=A(IJ)                                                   L  67
      IMAX=I                                                       L  68
20    CONTINUE                                                     L  69
C                                                                  L  70
C        TEST FOR PIVOT LESS THAN TOLERANCE (SINGULAR MATRIX)      L  71
C                                                                  L  72
      IF (ABS(BIGA)-TOL) 30,30,40                                  L  73
30    KS=1                                                         L  74
      RETURN                                                       L  75
C                                                                  L  76
C        INTERCHANGE ROWS IF NECESSARY                             L  77
C                                                                  L  78
40    I1=J+N*(J-2)                                                 L  79
      IT=IMAX-J                                                    L  80
```

```
      DO 50 K=J,N                                                    L  81
      I1=I1+N                                                        L  82
      I2=I1+IT                                                       L  83
      SAVE=A(I1)                                                     L  84
      A(I1)=A(I2)                                                    L  85
      A(I2)=SAVE                                                     L  86
C                                                                    L  87
C        DIVIDE EQUATION BY LEADING COEFFICIENT                      L  88
C                                                                    L  89
      SAVE=B(IMAX)                                                   L  90
50    A(I1)=A(I1)/BIGA                                               L  91
      B(IMAX)=B(J)                                                   L  92
      B(J)=SAVE/BIGA                                                 L  93
C                                                                    L  94
C        ELIMINATE NEXT VARIABLE                                     L  95
C                                                                    L  96
      IF (J-N) 60,90,60                                              L  97
60    IQS=N*(J-1)                                                    L  98
      DO 80 IX=JY,N                                                  L  99
      IXJ=IQS+IX                                                     L 100
      IT=J-IX                                                        L 101
      DO 70 JX=JY,N                                                  L 102
      IXJX=N*(JX-1)+IX                                               L 103
      JJX=IXJX+IT                                                    L 104
70    A(IXJX)=A(IXJX)-(A(IXJ)*A(JJX))                                L 105
80    B(IX)=B(IX)-(B(J)*A(IXJ))                                      L 106
C                                                                    L 107
C        BACK SOLUTION                                               L 108
C                                                                    L 109
90    NY=N-1                                                         L 110
      IT=N*N                                                         L 111
      DO 100 J=1,NY                                                  L 112
      IA=IT-J                                                        L 113
      IB=N-J                                                         L 114
      IC=N                                                           L 115
      DO 100 K=1,J                                                   L 116
      B(IB)=B(IB)-A(IA)*B(IC)                                        L 117
      IA=IA-N                                                        L 118
100   IC=IC-1                                                        L 119
      RETURN                                                         L 120
      END                                                            L 121-
      SUBROUTINE EFFCY                                               M   1
      REAL L,JAVG,ICUR,ICURO,IEXT,IINT,IINTO,I23,JC,JINT,JMAX,JMO,JPO,  M   2
     1MJM,MJP,MJMDF,MJPDF,MJDSP,MTEM                                 M  2A
      COMMON /CIRT/ USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2,  M   3
     1RD,LD,R(3),L(3),C(3),CP,T1,IEFCY,VDD                           M   4
      COMMON /EFCY/ AMP,AMP2,PHASE,PJ,PV,PHASE2,PJ2,PV2,DTP,GNEG,RFP,EFF  M   5
     1,AMPVDC,AMPJDC,DCPWR,AMPV,AMPV2                                M   6
      COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ,  M   7
     1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN  M   8
     2SPL,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC      M   9
      COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT,  M  10
     1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM,  M  11
     2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO  M  12
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```
      COMMON /PLO/ TIME(401),VOLT(401),CURR(401),JAVG(401),CURR1(401),     M  13
     1CURR2(401),CURR3(401),CLTT(401),TAVR(401)                            M  14
      DATA DPR/57.295780/                                                  M  15
C     CALCULATE TIME POINTS                                                M  16
      TP=2.*3.14159/OMEGA                                                  M  17
      TK=TIME(IPOINT)-TP                                                   M  18
      DO 10 I1=1,IPOINT                                                    M  19
      I2=IPOINT-I1+1                                                       M  20
      IF(TIME(I2).GT.TK) GO TO 10                                          M  21
      GO TO 20                                                             M  22
   10 CONTINUE                                                             M  23
   20 CJ=JAVG(I2)+(JAVG(I2+1)-JAVG(I2))*(TIME(I2)-TK)/DTP                  M  24
      VJ=VOLT(I2)+(VOLT(I2+1)-VOLT(I2))*(TIME(I2)-TK)/DTP                  M  25
      DTP2=TIME(I2+1)-TK                                                   M  26
      CT0=COS(OMEGA*TK)                                                    M  27
      CT1=COS(OMEGA*TIME(I2+1))                                            M  28
      CT2=COS(OMEGA*TIME(IPOINT))                                          M  29
      CT02=COS(2.*OMEGA*TK)                                                M  30
      CT12=COS(2.*OMEGA*TIME(I2+1))                                        M  31
      CT22=COS(2.*OMEGA*TIME(IPOINT))                                      M  32
      ST0=SIN(OMEGA*TK)                                                    M  33
      ST1=SIN(OMEGA*TIME(I2+1))                                            M  34
      ST2=SIN(OMEGA*TIME(IPOINT))                                          M  35
      ST02=SIN(2.*OMEGA*TK)                                                M  36
      ST12=SIN(2.*OMEGA*TIME(I2+1))                                        M  37
      ST22=SIN(2.*OMEGA*TIME(IPOINT))                                      M  38
      SUMJ1=(JAVG(I2+1)*CT1+JAVG(IPOINT)*CT2)/2.                           M  39
      SMJ1=(CJ*CT0+JAVG(I2+1)*CT1)/2.                                      M  40
      SUMJ2=(JAVG(I2+1)*ST1+JAVG(IPOINT)*ST2)/2.                           M  41
      SMJ2=(CJ*ST0+JAVG(I2+1)*ST1)/2.                                      M  42
      SUMJ12=(JAVG(I2+1)*CT12+JAVG(IPOINT)*CT22)/2.                        M  43
      SMJ12=(CJ*CT02+JAVG(I2+1)*CT12)/2.                                   M  44
      SUMJ22=(JAVG(I2+1)*ST12+JAVG(IPOINT)*ST22)/2.                        M  45
      SMJ22=(CJ*ST02+JAVG(I2+1)*ST12)/2.                                   M  46
      SUMV1=(VOLT(I2+1)*CT1+VOLT(IPOINT)*CT2)/2.                           M  47
      SMV1=(VJ*CT0+VOLT(I2+1)*CT1)/2.                                      M  48
      SUMV2=(VOLT(I2+1)*ST1+VOLT(IPOINT)*ST2)/2.                           M  49
      SMV2=(VJ*ST0+VOLT(I2+1)*ST1)/2.                                      M  50
      SUMV12=(VOLT(I2+1)*CT12+VOLT(IPOINT)*CT22)/2.                        M  51
      SMV12=(VJ*CT02+VOLT(I2+1)*CT12)/2.                                   M  62
      SUMV22=(VOLT(I2+1)*ST12+VOLT(IPOINT)*ST22)/2.                        M  53
      SMV22=(VJ*ST02+VOLT(I2+1)*ST12)/2.                                   M  54
      SUMJD=(JAVG(I2+1)+JAVG(IPOINT))/2.                                   M  55
      SMJD=(CJ+JAVG(I2+1))/2.                                              M  56
      SUMVD=(VOLT(I2+1)+VOLT(IPOINT))/2.                                   M  57
      SMVD= (VJ+VOLT(I2+1))/2.                                             M  58
      I22=I2+2                                                             M  59
      IP1=IPOINT-1                                                         M  60
      DO 30 J1=I22,IP1                                                     M  61
      CT=COS(OMEGA*TIME(J1))                                               M  62
      ST=SIN(OMEGA*TIME(J1))                                               M  63
      CT2=COS(2.*OMEGA*TIME(J1))                                           M  64
      ST2=SIN(2.*OMEGA*TIME(J1))                                           M  65
      SUMJ1=JAVG(J1)*C1+SUMJ1                                              M  66
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Appendix A

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      SUMJ2=JAVG(J1)*ST+SUMJ2                                          M  67
      SUMJ12=JAVG(J1)*CT2+SUMJ12                                       M  68
      SUMJ22=JAVG(J1)*ST2+SUMJ22                                       M  69
      SUMV1=VOLT(J1)*CT+SUMV1                                          M  70
      SUMV2=VOLT(J1)*ST+SUMV2                                          M  71
      SUMV12=VOLT(J1)*CT2+SUMV12                                       M  72
      SUMV22=VOLT(J1)*ST2+SUMV22                                       M  73
      SUMJD=JAVG(J1)+SUMJD                                             M  74
   30 SUMVD=VOLT(J1)+SUMVD                                             M  75
      SUMJ1=2.*(SUMJ1*DTP+SMJ1*DTP2)/TP                                M  76
      SUMJ2=2.*(SUMJ2*DTP+SMJ2*DTP2)/TP                                M  77
      SUMJ12=2.*(SUMJ12*DTP+SMJ12*DTP2)/TP                             M  78
      SUMJ22=2.*(SUMJ22*DTP+SMJ22*DTP2)/TP                             M  79
      SUMV1=2.*(SUMV1*DTP+SMV1*DTP2)/TP                                M  80
      SUMV2=2.*(SUMV2*DTP+SMV2*DTP2)/TP                                M  81
      SUMV12=2.*(SUMV12*DTP+SMV12*DTP2)/TP                             M  82
      SUMV22=2.*(SUMV22*DTP+SMV22*DTP2)/TP                             M  83
      AMPJDC=(SUMJD*DTP+SMJD*DTP2)/TP                                  M  84
      AMPVDC=(SUMVD*DTP+SMVD*DTP2)/TP                                  M  85
      AMPJ=SQRT(SUMJ1**2+SUMJ2**2)                                     M  86
      AMPV=SQRT(SUMV1**2+SUMV2**2)                                     M  87
      AMP2 =SQRT(SUMJ12**2+SUMJ22**2)                                  M  88
      AMPV2=SQRT(SUMV12**2+SUMV22**2)                                  M  89
      AMP=AMPJ                                                         M  90
      PJ=ATAN2(SUMJ2,SUMJ1)*DPR                                        M  91
      PV=ATAN2(SUMV2,SUMV1)*DPR                                        M  92
      IF(PJ.LT.0.) PJ=360.+PJ                                          M  93
      IF(PV.LT.0.) PV=360.+PV                                          M  94
      PHASE=PJ-PV                                                      M  95
      PJ2=ATAN2(SUMJ22,SUMJ12)*DPR                                     M  96
      PV2=ATAN2(SUMV22,SUMV12)*DPR                                     M  97
      IF(PJ2.LT.0.) PJ2=360.+PJ2                                       M  98
      IF(PV2.LT.0.) PV2=360.+PV2                                       M  99
      PHASE2=PJ2-PV2                                                   M 100
      GNEG=AMPJ*ABS(COS(PHASE/DPR))*S/AMPV                             M 101
      RFP=AMPV**2*GNEG/2.                                              M 102
      DCPWR =AMPVDC*AMPJDC*S                                           M 103
      EFF=RFP/DCPWR                                                    M 104
      RETURN                                                           M 105
      END                                                              M 106-
      BLOCK DATA                                                       N   1
      REAL JPDIF,JMDIF,MUP,MUM,NOP,NOM,MUPO ,JPO,JMAX,JDISPL,JC,IEXT,IIN  N   2
     1T,JINT,IINTO,L,JAVG,I23,ICUR,ICURO,JMO,MJP,MJM,MJPDF,MJMDF,MJDSP,   N   3
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```
2JCSAV,JPSAV,MUMO,NP,NM,JP,JM,JMSAV,NMSAV,NPSAV,MTEM                    N   4
 INTEGER PRTFRQ,EXTRAP                                                  N   5
 COMMON /ABC/ MODA,MODB,MODD,MODVP,MODVM,MODVNP,MODVNM,MODT,A1,A2,      N   6
1A3,A4,A5,A6,B1,B2,B3,B4,B5,B6,D1,D2,D3,D4,D5,D6,C1,C2,C3,C4,C5,C6,     N   7
2C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,MUP,MUM,MUPO,     N   8
3MUMO,AVP,AVM,NOP,NOM,VP1M,VM1M,CAT,CBT,PWRP,PWRM,TEMP                 N   9
 COMMON /CIRT/ USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2,    N  10
1RD,LD,R(3),L(3),C(3),CP,T1,IEFCY,VNEW                                 N  11
 COMMON /DSTR/ NP(201),NM(201),DN(201),TEM(201),E(201),DE(201),VSUM    N  12
1(201),VP(201),VM(201),JP(201),JM(201),JPDIF(201),JMDIF(201),JDISPL    N  13
2(201),RCMBR(201),ALPHA(201),BETA(201),TPRINT(201)                     N  14
 COMMON /EFCY/ AMP,AMP2,PHASE,PJ,PV,PHASE2,PJ2,PV2,DTP,GNEG,RFP,EFF    N  15
1,AMPVDC,AMPJDC,DCPWR,AMPV,AMPV2                                       N  16
 COMMON /FUND/ M,MP1,N3S,PRTFRQ,NXPRNT(6),MODP,MODFCH,EXTRAP,MS,IJ,    N  17
1IPOINT,FM,STEPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DEN    N  18
2SPL,DENSMI,DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC             N  19
 COMMON /MJV/ JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT,    N  20
1DVDT,DVDTO,VC(3),VCO(3),DVC(3),DVCO(3),ICUR(3), ICURO(3),MJP,MJM,     N  21
2MJPDF,MJMDF,MJDSP,MTEM,VPMAX,VMMAX,CST(10,3),DMTEM,DDIDT,DIDTO        N  22
 COMMON /PLO/ TIME(401),VOLT(401),CURR(401),JAVG(401),CURR1(401),      N  23
1CURR2(401),CURR3(401),CLTT(401),TAVR(401)                             N  24
 COMMON /SAV/ NPSAV(201),NMSAV(201),ESAV(201),VXSAV(201),VPSAV(201)    N  25
1,VMSAV(201),JPSAV(201),JMSAV(201),VSAV,TSAV,JCSAV,GAMSAV,TMPSAV       N  26
 DATA MODA,MODB,MODD,MODVP,MODVM,MODVNP,MODVNM,MODT,A1,A2,A3,A4,A5,     N  31
1A6,B1,B2,B3,B4,B5,B6,D1,D2,D3,D4,D5,D6,C1,C2,C3,C4,C5,C6,C7,C8,C9,    N  32
2C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,MUP,MUM,MUPO,MUMO,AVP,    N  33
3AVM,NOP,NOM,VP1M,VM1M,CAT,CBT,PWRP,PWRM,TEMP/8*0,53*0.                N  34
 DATA USTAT,U,V,DU,VO,V1,V2,OMEGA,OMEGA1,OMEGA2,PHI1,PHI2,R,L,C,CP,     N  35
1T1,IEFCY/23*0.,0/                                                     N  36
 DATA AMP,AMP2,PHASE,PJ,PV,PHASE2,PJ2,PV2,DTP,GNEG,RFP,EFF,AMPVDC,     N  37
1AMPJDC,DCPWR,AMPV,AMPV2/17*0./                                        N  38
 DATA M,MP1,N3S,PRTFRQ,NXPRNT,MODP,MODFCH,EXTRAP,MS,IJ,IPOINT,FM,ST     N  39
1EPFA,DX,DT,T,D,S,P,EL,EPSO,DIELK,DNSTY,SPCHT,THCND,DENSPL,DENSMI,     N  40
2DENS2,DENS2T,REC,EGAP,GAMSEC,GAMI,GAMMA,TAUSEC/16*0,24*0./            N  41
 DATA NP,NM,DN,TEM,E,DE,VSUM,VP,VM,JP,JM,JPDIF,JMDIF,JDISPL,RCMBR,     N  42
1ALPHA,BETA,TPRINT/1918*0./                                            N  43
 DATA JPO,JMO,JMAX,DJMAXM,JC,JINT,IINT,IINTO,IEXT,I23,DIDT,DVDT,DVD    N  44
1TO,VC,VCO,DVC,DVCO,ICUR,ICURO,MJP,MJM,MJPDF,MJMDF,MJDSP,MTEM,VPMAX    N  45
2,VMMAX,CST,DMTEM/70*0./                                               N  46
 DATA TIME,VOLT,CURR,JAVG,CURR1,CURR2,CURR3/2807*0./                   N  47
 DATA NPSAV,NMSAV,ESAV,VXSAV,VPSAV,VMSAV,JPSAV,JMSAV,VSAV,TSAV,JCSA    N  48
1V,GAMSAV,TMPSAV/813*0./                                               N  49
 END                                                                   N  50-
```

Appendix B.—Sample Output of Program DIODE

```
REV BIAS D=2.0-4 V=4SIN5.89+10T NEW P,N(X) NO AVAL M=100 11FEB91

              MODA                A1                  A2                  A3                  A4                  A5
                 1  7.0300000E+05       1.2310000E+06       7.0300000E+05       1.2310000E+06       1.0000000E+06
              MODB                B1                  B2                  B3                  B4                  B5
                 1  1.5820000E+06       2.0360000E+06       6.7100000E+05       1.6930000E+06       4.0000000E+05
              MODD                D1                  D2                  D3                  D4                  D5
                 0  0.0000000E+00       0.0000000E+00       0.0000000E+00       0.0000000E+00       0.0000000E+00
              MODT                CAT                 CBT                PWRM                PWRP              TEMP K
                 0  2.0000001E-03       2.0000001E-03       2.5000000E+00       2.6999998E+00       3.0000000E+02
                           DENSITY            SPEC HT            THRM CND
                    2.3280001E+00       6.9999999E-01       1.4499998E+00
              MODVP               MUP                 C1                  C2                  C3                  C4
                 1  4.0000000E+02       2.0000007E-05       1.6000000E+04       2.0000000E+04       1.0000000E+07
             MODVNP              MUPO                AVP                 NOP                VP1M
                 0  4.7699997E-01       7.5999999E-01       6.3000002E+16       3.7000000E+06
              MODVM               MUM                 C5                  C6                  C7                  C8
                 1  1.2000000E+03       4.4000000E-05       4.4000000E+04       7.0000000E+03       1.0000000E+07
             MODVNM              MUMO                AVM                 NOM                VM1M
                 0  6.5000000E+01       7.2000003E-01       8.5000014E+16       4.0000000E+06
                                 C9                 C10                 C15                 C20
                   -1.5500000E+07      -1.3000000E+06       1.0000000E+05       2.0000000E+04
          GAMSEC             TAUSEC               GAMMA                GAMI                JMO                 JPO
   0.000000E+00       0.000000E+00       0.000000E+00       0.000000E+00       1.000000E-07       1.000000E-07
            USTAT                DU                  VO               OMEGA                T1                  V
   0.000000E+00       0.000000E+00       4.000000E+00       5.890000E+10       0.000000E+00       1.000000E+00
              V1              OMEGA1                PHI1                V2           OMEGA2                PHI2      IEFCY
   0.000000E+00       0.000000E+00       0.000000E+00       0.000000E+00       0.000000E+00       0.000000E+00          0
               P                   D                   S                   T             DVDT               JMAX
   1.000000E+00       2.000000E-04       1.260000E-05       5.000000E-12       9.999999E+09       2.000000E+06
          CIRCUIT PARAMETERS WITH CP=       9.999998E-14
            ICIR                   R                   L                   C                  VC                 DVC
               1       4.000000E+02       0.000000E+00       1.000000E+30       0.000000E+00       0.000000E+00
               2       0.000000E+00       0.000000E+00       1.000000E+30       0.000000E+00       0.000000E+00
               3       0.000000E+00       0.000000E+00       1.000000E+30       0.000000E+00       0.000000E+00
     STEPFA          DJMAXM          DIELK          DENSPL          DENSNI          DENS2          REC          EGAP
 1.0000E-01      9.0000E+00      1.1800E+01      1.0000E+00      1.0000E+00      2.0000E+20      1.0000E+03      1.1200E+00
       M       PRTFRQ          N3S          MODP       MODFCH       EXTRAP          MS          IPOINT
     100            3            1             1            2            0         999             101
 NXPRNT
16 17 18 19  8 13
TPRINT LIST          3   VALUES
   5.00000E-12     1.10000E-11     1.70000E-11

                                    A6                  B6                  D6                  C9                 C10
                          1.230999E+06        1.692929E+06        0.000000E+00       -1.550000E+07       -1.300000E+06
                                   C11                 C12                 C13                 C14
                          2.8961850E+06       1.1113196E+02      -8.3458517E-04       1.8761110E-09
                                   C16                 C17                 C18                 C19
                          1.9704380E+06       6.2841455E+02      -1.0128904E-02      -1.7557903E-07
```

T= 5.000000E-12 V= 1.000000E+00

M	N+	N-	DN	TEMP K
0	9.800000E+17	1.300000E+17	-8.500000E+17	3.000000E+02
1	9.500000E+17	1.600000E+17	-7.900000E+17	3.000000E+02
2	9.000000E+17	1.800000E+17	-7.200000E+17	3.000000E+02
3	8.500000E+17	1.900000E+17	-6.600000E+17	3.000000E+02
4	8.200000E+17	2.000000E+17	-6.200000E+17	3.000000E+02
5	7.600000E+17	2.000000E+17	-5.600000E+17	3.000000E+02
6	7.200000E+17	2.100000E+17	-5.100000E+17	3.000000E+02
7	6.800000E+17	2.200000E+17	-4.600000E+17	3.000000E+02
8	6.200000E+17	2.200000E+17	-4.000000E+17	3.000000E+02
9	5.700000E+17	2.200000E+17	-3.500000E+17	3.000000E+02
10	5.300000E+17	2.200000E+17	-3.100000E+17	3.000000E+02
11	4.800000E+17	2.200000E+17	-2.600000E+17	3.000000E+02
12	4.300000E+17	2.200000E+17	-2.100000E+17	3.000000E+02
13	3.800000E+17	2.100000E+17	-1.700000E+17	3.000000E+02
14	3.400000E+17	2.100000E+17	-1.300000E+17	3.000000E+02
15	3.000000E+17	2.000000E+17	-1.000000E+17	3.000000E+02
16	2.800000E+17	1.900000E+17	-8.700003E+16	3.000000E+02
17	2.600000E+17	1.800000E+17	-7.500002E+16	3.000000E+02
18	2.400000E+17	1.800000E+17	-6.400000E+16	3.000000E+02
19	2.200000E+17	1.700000E+17	-5.400000E+16	3.000000E+02
20	2.000000E+17	1.600000E+17	-4.400000E+16	3.000000E+02
21	1.900000E+17	1.500000E+17	-3.600000E+16	3.000000E+02
22	1.900000E+17	1.500000E+17	-2.800000E+16	3.000000E+02
23	1.700000E+17	1.400000E+17	-2.000000E+16	3.000000E+02
24	1.600000E+17	1.400000E+17	-1.400000E+16	3.000000E+02
25	1.400000E+17	1.300000E+17	-9.999998E+15	3.000000E+02
26	1.300000E+17	1.200000E+17	-6.100000E+15	3.000000E+02
27	1.200000E+17	1.100000E+17	-3.800000E+15	3.000000E+02
28	1.100000E+17	1.100000E+17	-2.600000E+15	3.000000E+02
29	1.000000E+17	1.000000E+17	-1.600000E+15	3.000000E+02
30	9.700002E+16	9.500000E+16	-9.999999E+14	3.000000E+02
31	9.099998E+16	8.999997E+16	-5.600001E+14	3.000000E+02
32	8.500001E+16	8.500001E+16	-2.100000E+14	3.000000E+02
33	7.999999E+16	7.999999E+16	-1.900000E+14	3.000000E+02
34	7.699997E+16	7.699997E+16	-9.999999E+13	3.000000E+02
35	7.699997E+16	7.699997E+16	0.000000E+00	3.000000E+02
36	7.699997E+16	7.699997E+16	1.400000E+14	3.000000E+02
37	7.699997E+16	7.799997E+16	2.400000E+14	3.000000E+02
38	7.699997E+16	7.799997E+16	3.200000E+14	3.000000E+02
39	7.799997E+16	7.799997E+16	4.000000E+14	3.000000E+02
40	7.799997E+16	7.799997E+16	5.000000E+14	3.000000E+02
41	7.799997E+16	7.899998E+16	5.500001E+14	3.000000E+02
42	7.799997E+16	7.899998E+16	6.200000E+14	3.000000E+02
43	7.799997E+16	7.899998E+16	6.899999E+14	3.000000E+02
44	7.799997E+16	7.899998E+16	7.500001E+14	3.000000E+02
45	7.799997E+16	7.899998E+16	7.999999E+14	3.000000E+02
46	7.799997E+16	7.899998E+16	8.500001E+14	3.000000E+02
47	7.799997E+16	7.899998E+16	8.899999E+14	3.000000E+02
48	7.799997E+16	7.899998E+16	9.300000E+14	3.000000E+02
49	7.699997E+16	7.899998E+16	9.600001E+14	3.000000E+02
50	7.699997E+16	7.899998E+16	9.999999E+14	3.000000E+02
51	7.699997E+16	7.799997E+16	9.999999E+14	3.000000E+02
52	7.699997E+16	7.799997E+16	9.999999E+14	3.000000E+02
53	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
54	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
55	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
56	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02

57	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
58	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
59	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
60	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
61	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
62	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
63	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
64	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
65	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
66	7.600003E+16	7.699997E+16	9.999999E+14	3.000000E+02
67	7.699997E+16	7.799997E+16	9.999999E+14	3.000000E+02
68	7.799997E+16	7.899998E+16	9.999999E+14	3.000000E+02
69	7.899998E+16	7.999999E+16	9.999999E+14	3.000000E+02
70	8.099999E+16	8.200000E+16	9.999999E+14	3.000000E+02
71	8.300000E+16	8.400001E+16	9.999999E+14	3.000000E+02
72	8.400001E+16	8.500001E+16	9.999999E+14	3.000000E+02
73	8.500001E+16	8.600002E+16	9.999999E+14	3.000000E+02
74	8.700003E+16	8.899997E+16	9.999999E+14	3.000000E+02
75	8.999997E+16	9.199999E+16	9.999999E+14	3.000000E+02
76	9.500000E+16	9.700002E+16	9.999999E+14	3.000000E+02
77	1.000000E+17	1.000000E+17	9.999999E+14	3.000000E+02
78	1.100000E+17	1.000000E+17	9.999999E+14	3.000000E+02
79	1.100000E+17	1.100000E+17	9.999999E+14	3.000000E+02
80	1.200000E+17	1.200000E+17	9.999999E+14	3.000000E+02
81	1.300000E+17	1.300000E+17	1.100000E+15	3.000000E+02
82	1.400000E+17	1.300000E+17	1.200000E+15	3.000000E+02
83	1.400000E+17	1.400000E+17	1.350000E+15	3.000000E+02
84	1.500000E+17	1.500000E+17	1.600000E+15	3.000000E+02
85	1.500000E+17	1.500000E+17	2.000000E+15	3.000000E+02
86	1.600000E+17	1.600000E+17	2.500000E+15	3.000000E+02
87	1.700000E+17	1.700000E+17	3.200000E+15	3.000000E+02
88	1.900000E+17	2.000000E+17	4.400000E+15	3.000000E+02
89	2.100000E+17	2.200000E+17	6.399999E+15	3.000000E+02
90	2.200000E+17	2.300000E+17	9.999998E+15	3.000000E+02
91	2.200000E+17	2.400000E+17	1.700000E+16	3.000000E+02
92	2.300000E+17	2.600000E+17	2.800000E+16	3.000000E+02
93	2.300000E+17	2.800000E+17	4.700000E+16	3.000000E+02
94	2.200000E+17	3.000000E+17	7.200000E+16	3.000000E+02
95	2.200000E+17	3.200000E+17	1.000000E+17	3.000000E+02
96	2.100000E+17	3.800000E+17	1.700000E+17	3.000000E+02
97	2.000000E+17	4.800000E+17	2.800000E+17	3.000000E+02
98	1.900000E+17	6.600000E+17	4.700000E+17	3.000000E+02
99	1.500000E+17	9.700000E+17	7.200000E+17	3.000000E+02
100	5.100000E+16	1.100000E+18	1.000000E+18	3.000000E+02

T	V	U	J+AVG	J-AVG	J AVG	GAMA
5.000000E-12	1.000000E+00	1.161045E+00	8.434869E+04	1.002301E+05	1.845788E+05	0.000000E+00
DT	V+MAX	V-MAX	I EXT	I INT	J INT	DV/DT
0.000000E+00	7.162934E+06	9.999998E+06	4.026126E-04	2.131409E+00	1.691594E+05	9.999999E+09
D*ALPHAAVG	A*J-AVG	D*BETAAVG	B*J+AVG	RECOMRATAVG	I23	DI/DT
7.633076E-09	6.726215E+01	1.063382E-13	3.111985E-05	4.254728E+08	0.000000E+00	0.000000E+00
J+DIF	J-DIF	J DIF	J DISPL	AVE TEMP K	TEM RATE	DENS2T
-4.842207E+03	-1.062931E+04	-1.547152E+04	5.223843E+01	3.000000E+02	0.000000E+00	2.000000E+20

X	E(X)	N+(X)	N-(X)	J+(X)	J-(X)	NET Q	J TOTAL
0.000E+00	1.80237E+04	9.80000E+17	1.30000E+17	7.23944E+05	1.87007E+05	6.87195E+10	8.64253E+05
6.000E-06	1.64901E+04	8.50000E+17	1.90000E+17	6.02034E+05	2.67628E+05	0.00000E+00	8.36532E+05
1.200E-05	1.64899E+04	7.20000E+17	2.10000E+17	5.09957E+05	2.95799E+05	0.00000E+00	7.72625E+05
1.800E-05	1.59788E+04	5.70000E+17	2.20000E+17	3.97168E+05	3.06989E+05	6.87195E+10	6.78895E+05
2.400E-05	1.59788E+04	4.30000E+17	2.20000E+17	2.99619E+05	3.06989E+05	6.87195E+10	5.84166E+05
3.000E-05	1.34230E+04	3.00000E+17	2.00000E+17	1.88793E+05	2.61351E+05	0.00000E+00	4.44610E+05
3.600E-05	1.10716E+04	2.40000E+17	1.80000E+17	1.32585E+05	2.14800E+05	-3.99999E+15	3.41515E+05
4.200E-05	1.19916E+04	1.90000E+17	1.50000E+17	1.10998E+05	1.86180E+05	4.00003E+15	3.00764E+05
4.800E-05	4.73266E+03	1.60000E+17	1.40000E+17	4.39356E+04	1.00862E+05	5.99998E+15	1.43441E+05
5.400E-05	1.15434E+03	1.20000E+17	1.10000E+17	8.67256E+03	2.31732E+04	6.19999E+15	3.55927E+04
6.000E-05	7.76008E+02	9.70000E+16	9.50000E+16	4.74921E+03	1.36899E+04	1.00001E+15	2.68064E+04
6.600E-05	6.32281E+02	8.00000E+16	8.00000E+16	3.20074E+03	9.45463E+03	-1.90000E+14	1.90873E+04
7.200E-05	7.21703E+02	7.70000E+16	7.70000E+16	3.51003E+03	1.03450E+04	1.40000E+14	1.27066E+04
7.800E-05	9.78285E+02	7.80000E+16	7.80000E+16	4.79462E+03	1.40394E+04	4.00000E+14	1.92916E+04
8.400E-05	1.01093E+03	7.80000E+16	7.90000E+16	4.95132E+03	1.46719E+04	-3.80006E+14	1.96754E+04
9.000E-05	1.27154E+03	7.80000E+16	7.90000E+16	6.19458E+03	1.82326E+04	-2.00006E+14	2.44794E+04
9.600E-05	1.44371E+03	7.80000E+16	7.90000E+16	7.00853E+03	2.05353E+04	-7.00058E+13	2.71947E+04
1.020E-04	1.97780E+03	7.70000E+16	7.80000E+16	9.37395E+03	2.70792E+04	-5.90558E+09	3.76375E+04
1.080E-04	2.02885E+03	7.60000E+16	7.70000E+16	9.48091E+03	2.73544E+04	6.28139E+10	3.68876E+04
1.140E-04	2.02876E+03	7.60000E+16	7.70000E+16	9.48052E+03	2.73534E+04	6.28139E+10	3.68861E+04
1.200E-04	2.02868E+03	7.60000E+16	7.70000E+16	9.48014E+03	2.73523E+04	6.28139E+10	3.68847E+04
1.260E-04	2.02859E+03	7.60000E+16	7.70000E+16	9.47977E+03	2.73514E+04	6.28139E+10	3.68834E+04
1.320E-04	2.02851E+03	7.60000E+16	7.70000E+16	9.47940E+03	2.73504E+04	6.28139E+10	3.61491E+04
1.380E-04	2.02843E+03	7.90000E+16	8.00000E+16	9.85318E+03	2.84149E+04	-5.90558E+09	3.61218E+04
1.440E-04	2.02835E+03	8.40000E+16	8.50000E+16	1.04764E+04	3.01898E+04	-5.90558E+09	3.92528E+04
1.500E-04	2.48836E+03	9.00000E+16	9.20000E+16	1.36383E+04	3.91957E+04	-1.00001E+15	4.71939E+04
1.560E-04	9.54715E+02	1.10000E+17	1.00000E+17	6.60192E+03	1.75846E+04	1.10000E+16	1.64135E+04
1.620E-04	-2.02557E+03	1.30000E+17	1.30000E+17	-1.61923E+04	-4.61156E+04	1.10000E+15	-6.56190E+04
1.680E-04	-5.77774E+03	1.50000E+17	1.50000E+17	-4.91243E+04	-1.24267E+05	1.60000E+15	-1.78932E+05
1.740E-04	-7.38296E+03	1.70000E+17	1.70000E+17	-6.85597E+04	-2.72374E+05	3.20000E+15	-3.86301E+05
1.800E-04	-5.05205E+03	2.20000E+17	2.30000E+17	-6.40334E+04	-1.73744E+05	-6.01295E+10	-2.53298E+05
1.860E-04	-1.01381E+03	2.30000E+17	2.80000E+17	-1.46408E+04	-5.21429E+04	-2.99995E+15	-1.18173E+05
1.920E-04	8.54513E+03	2.10000E+17	3.80000E+17	9.53499E+04	3.95205E+05	0.00000E+00	3.58150E+05
1.980E-04	4.42766E+04	1.50000E+17	9.70000E+17	1.52452E+05	1.55413E+06	-1.00000E+17	1.58336E+06

T	V	U	J+AVG	J-AVG	J AVG	GAMA
1.103353E-11	1.323382E-01	2.420347E+00	-8.583965E+03	-1.350179E+04	-2.208575E+04	0.000000E+00
DT	V+MAX	V-MAX	I EXT	I INT	J INT	DV/DT
4.075427E-14	9.927717E+05	2.780752E+06	5.720019E-03	-1.747467E+00	-1.386879E+05	-1.758418E+13
D*ALPHAAVG	A*J-AVG	D*BETAAVG	B*J+AVG	RECOMRATAVG	I23	DI/DT
1.734154E-54	-1.239933E-44	0.000000E+00	0.000000E+00	2.409533E+08	0.000000E+00	-8.612138E+13
J+DIF	J-DIF	J DIF	J DISPL	AVE TEMP K	TEM RATE	DENS2T
-4.409914E+03	-1.983993E+04	-2.424984E+04	-9.235231E+04	3.000000E+02	0.000000E+00	2.000000E+20

X	E(X)	N+(X)	N-(X)	J+(X)	J-(X)	NET Q	J TOTAL
0.000E+00	-1.30072E+03	5.55062E+17	4.24142E+05	-4.50666E+04	9.99997E-08	-2.94938E+17	2.44522E+05
6.000E-06	-3.38397E+03	1.09655E+18	1.57591E+17	-2.21715E+05	-8.72651E+04	2.78954E+17	-5.42529E+05
1.200E-05	-2.21912E+03	3.75069E+17	5.12069E+16	-5.09745E+04	-1.97145E+04	-1.86138E+17	-2.38653E+05
1.800E-05	-2.44504E+03	6.83602E+17	1.76077E+17	-1.01881E+05	-7.38679E+04	1.57525E+17	-2.79197E+05
2.400E-05	-7.66389E+02	3.29274E+17	1.06992E+17	-1.59249E+04	-1.52335E+04	1.22825E+16	-1.69981E+05
3.000E-05	-1.13376E+03	2.46076E+17	1.43842E+17	-1.74745E+04	-2.97907E+04	2.23366E+15	-2.07772E+05
3.600E-05	-9.23278E+02	2.07167E+17	1.42388E+17	-1.20320E+04	-2.42489E+04	7.79309E+14	-1.44250E+05
4.200E-05	-2.70950E+02	1.64605E+17	1.29168E+17	-2.84282E+03	-6.64862E+03	-5.62327E+14	-1.07237E+05
4.800E-05	3.80708E+01	1.40232E+17	1.27394E+17	3.41890E+02	9.30918E+02	-1.16183E+15	-9.05007E+04
5.400E-05	7.86330E+02	1.10266E+17	1.07278E+17	5.46940E+03	1.56574E+04	-8.11459E+14	-5.85312E+04
6.000E-05	1.53017E+03	9.15958E+16	9.14595E+16	8.70752E+03	2.50956E+04	-8.63729E+14	-3.73233E+04
6.600E-05	2.20341E+03	7.95928E+16	8.01253E+16	1.07442E+04	3.06532E+04	-7.22576E+14	-2.70162E+04
7.200E-05	2.59063E+03	7.44034E+16	7.46337E+16	1.17130E+04	3.29365E+04	-9.02790E+13	-2.49017E+04
7.800E-05	2.57406E+03	7.46719E+16	7.49962E+16	1.16842E+04	3.29119E+04	7.56440E+13	-2.61324E+04
8.400E-05	2.51790E+03	7.52355E+16	7.58310E+16	1.15292E+04	3.26430E+04	2.44083E+13	-2.65973E+04
9.000E-05	2.50085E+03	7.53133E+16	7.61057E+16	1.14671E+04	3.25668E+04	7.66437E+12	-2.66932E+04
9.600E-05	2.50452E+03	7.51421E+16	7.60991E+16	1.14569E+04	3.26058E+04	-2.69874E+13	-2.64328E+04
1.020E-04	2.54224E+03	7.45395E+16	7.56004E+16	1.15270E+04	3.28187E+04	-6.09601E+13	-2.57351E+04
1.080E-04	2.59694E+03	7.38030E+16	7.48529E+16	1.16453E+04	3.31034E+04	-4.98962E+13	-2.50677E+04
1.140E-04	2.61874E+03	7.35621E+16	7.45630E+16	1.16993E+04	3.32160E+04	-8.99259E+11	-2.50174E+04
1.200E-04	2.61845E+03	7.35718E+16	7.45715E+16	1.16996E+04	3.32165E+04	3.37692E+11	-2.50437E+04
1.260E-04	2.61909E+03	7.35582E+16	7.45608E+16	1.17001E+04	3.32188E+04	-2.61725E+12	-2.50426E+04
1.320E-04	2.59288E+03	7.39474E+16	7.48743E+16	1.16508E+04	3.30678E+04	7.31116E+13	-2.58159E+04
1.380E-04	2.43070E+03	7.63488E+16	7.70661E+16	1.13153E+04	3.21639E+04	2.82637E+14	-2.91108E+04
1.440E-04	2.14908E+03	8.05748E+16	8.12681E+16	1.06206E+04	3.04040E+04	3.06689E+14	-3.38622E+04
1.500E-04	1.78803E+03	8.66896E+16	8.71658E+16	9.57862E+03	2.76079E+04	5.23705E+14	-4.22704E+04
1.560E-04	1.13228E+03	1.00185E+17	1.00341E+17	7.10537E+03	2.07557E+04	8.43801E+14	-6.16560E+04
1.620E-04	3.31951E+02	1.20839E+17	1.20992E+17	2.55366E+03	7.60921E+03	9.46343E+14	-9.17896E+04
1.680E-04	-2.69437E+02	1.38249E+17	1.39470E+17	-2.37438E+03	-7.13935E+03	3.78442E+14	-1.15334E+05
1.740E-04	-9.48636E+02	1.61328E+17	1.63325E+17	-9.62202E+03	-2.85453E+04	1.20239E+15	-1.70189E+05
1.800E-04	-1.85715E+03	1.95197E+17	2.04572E+17	-2.23696E+04	-6.70761E+04	6.24944E+14	-2.34833E+05
1.860E-04	-2.33653E+03	2.01908E+17	2.56712E+17	-2.88214E+04	-1.03467E+05	-7.80406E+15	-2.76079E+05
1.920E-04	-1.84712E+03	1.02043E+17	1.95802E+17	-1.16334E+04	-6.38845E+04	7.62411E+16	-3.72315E+05
1.980E-04	-3.82560E+03	1.49937E+16	8.02376E+17	-3.39483E+03	-4.90827E+05	-6.73823E+16	-1.09112E+06

T	V	U	J+AVG	J-AVG	J AVG	GAMA
1.704351E-11	1.676113E-01	3.374206E+00	-1.574474E+03	2.540905E+04	2.383457E+04	0.000000E+00
DT	V+MAX	V-MAX	I EXT	I INT	J INT	DV/DT
6.047192E-14	6.591936E+06	9.999986E+06	8.016482E-03	5.823381E-02	4.621730E+03	1.227356E+11
D*ALPHAAVG	A*J-AVG	D*BETAAVG	B*J+AVG	RECOMRATAVG	I23	DI/DT
1.285253E-11	8.127230E-02	2.749508E-18	1.374781E-21	1.529768E+08	0.000000E+00	1.033080E+12
J+DIF	J-DIF	J DIF	J DISPL	AVE TEMP K	TEM RATE	DENS2T
-4.673672E+03	-1.549475E+04	-2.016842E+04	9.555830E+02	3.000000E+02	0.000000E+00	2.000000E+20

X	E(X)	N+(X)	N-(X)	J+(X)	J-(X)	NET Q	J TOTAL
0.000E+00	-5.47349E+02	5.86297E+17	9.73698E+05	-2.03413E+04	9.99999E-08	-2.63704E+17	3.34330E+05
6.000E-06	-7.44116E+02	8.76491E+17	1.27084E+16	-4.11768E+04	-1.75862E+03	2.03783E+17	-1.00751E+05
1.200E-05	-1.53010E+03	3.31621E+17	1.05958E+17	-3.15239E+04	-2.90724E+04	-2.84337E+17	-1.11015E+05
1.800E-05	-6.65158E+02	6.53785E+17	9.03311E+16	-2.74992E+04	-1.12140E+04	2.13454E+17	-2.05503E+04
2.400E-05	1.02947E+03	2.02027E+17	4.45731E+16	1.30546E+04	8.42269E+03	-5.25463E+16	-4.48500E+04
3.000E-05	-1.13310E+02	2.26060E+17	1.11403E+17	-1.63789E+03	-2.41487E+03	1.46573E+16	-6.92399E+04
3.600E-05	-3.64028E+01	1.88802E+17	1.17174E+17	-4.40151E+02	-8.18779E+02	7.62824E+15	1.40059E+04
4.200E-05	6.31965E+01	1.47733E+17	1.10395E+17	5.97583E+02	1.33761E+03	1.33818E+15	-3.55527E+03
4.800E-05	8.74358E+01	1.26357E+17	1.12890E+17	7.06816E+02	1.89046E+03	-5.32632E+14	-9.69368E+03
5.400E-05	1.90568E+02	1.03043E+17	9.98571E+16	1.25369E+03	3.62803E+03	-6.13615E+14	-1.39270E+02
6.000E-05	3.06301E+02	8.78897E+16	8.71615E+16	1.71472E+03	5.06381E+03	-2.71848E+14	5.90738E+03
6.600E-05	3.97981E+02	7.77050E+16	7.76908E+16	1.96615E+03	5.84060E+03	-1.75844E+14	5.30836E+03
7.200E-05	4.61686E+02	7.22906E+16	7.24577E+16	2.11922E+03	6.30109E+03	-2.71258E+13	2.38938E+03
7.800E-05	4.61667E+02	7.20533E+16	7.24406E+16	2.11218E+03	6.29935E+03	1.27700E+13	1.07776E+03
8.400E-05	4.52706E+02	7.26378E+16	7.32453E+16	2.08836E+03	6.24822E+03	1.24511E+13	1.27201E+03
9.000E-05	4.48896E+02	7.28018E+16	7.36009E+16	2.07562E+03	6.22678E+03	9.29860E+11	1.41639E+03
9.600E-05	4.49067E+02	7.26821E+16	7.36153E+16	2.07299E+03	6.23031E+03	-3.14177E+12	1.64708E+03
1.020E-04	4.53217E+02	7.22474E+16	7.32654E+16	2.07946E+03	6.25684E+03	-1.80104E+13	1.86006E+03
1.080E-04	4.61619E+02	7.16009E+16	7.26093E+16	2.09870E+03	6.31338E+03	-8.42404E+12	1.88194E+03
1.140E-04	4.65034E+02	7.13110E+16	7.23116E+16	2.10552E+03	6.33304E+03	-6.28676E+11	1.66285E+03
1.200E-04	4.65100E+02	7.12975E+16	7.22975E+16	2.10542E+03	6.33268E+03	4.13391E+10	1.61151E+03
1.260E-04	4.65133E+02	7.12967E+16	7.22968E+16	2.10554E+03	6.33306E+03	-1.30460E+11	1.58507E+03
1.320E-04	4.60668E+02	7.16771E+16	7.26651E+16	2.09665E+03	6.30549E+03	1.20114E+13	1.07260E+03
1.380E-04	4.36208E+02	7.37164E+16	7.46751E+16	2.04281E+03	6.14258E+03	4.12945E+13	-1.62450E+02
1.440E-04	3.94995E+02	7.75513E+16	7.85057E+16	1.94766E+03	5.85837E+03	4.55551E+13	-1.11175E+03
1.500E-04	3.41145E+02	8.33139E+16	8.42354E+16	1.80909E+03	5.44206E+03	7.84717E+13	-3.70502E+03
1.560E-04	2.42661E+02	9.55029E+16	9.63737E+16	1.47802E+03	4.44831E+03	1.29187E+14	-9.66826E+03
1.620E-04	1.07132E+02	1.14428E+17	1.15324E+17	7.83960E+02	2.36419E+03	2.03623E+14	-1.67000E+04
1.680E-04	-2.69753E+01	1.30293E+17	1.31740E+17	-2.25128E+02	-6.82443E+02	1.52974E+14	-1.87154E+04
1.740E-04	-2.30863E+02	1.51463E+17	1.54269E+17	-2.23063E+03	-6.77791E+03	3.94390E+14	-4.50159E+04
1.800E-04	-4.91329E+02	1.74671E+17	1.83435E+17	-5.44604E+03	-1.69536E+04	1.23545E+15	-6.22069E+04
1.860E-04	-9.62220E+02	1.82194E+17	2.45360E+17	-1.10191E+04	-4.34699E+04	-1.61659E+16	-6.53396E+04
1.920E-04	2.34454E+03	2.60864E+16	5.64096E+16	3.73588E+03	2.28047E+04	1.39677E+17	-2.27752E+05
1.980E-04	2.11441E+04	3.22089E+15	1.12065E+18	2.52379E+03	1.63450E+06	-3.97430E+17	1.82638E+06

CAPACITOR VOLTAGES AT LAST SUCCESSFUL PRINTOUT

VC1	DVC1	VC2	DVC2	VC3	DVC3
0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00

T	V	I	JAVG	I1	I2
5.000000E-12	1.000000E+00	2.131409E+00	1.845788E+05	4.026126E-04	0.000000E+00
5.182202E-12	1.080660E+00	3.009988E+00	1.911363E+05	2.476267E-03	0.000000E+00
5.243653E-12	2.903447E-01	-1.701361E+00	8.655875E+03	1.134390E-03	0.000000E+00
5.373293E-12	1.598604E+00	4.329266E+00	2.406202E+05	1.861963E-03	0.000000E+00
5.490972E-12	1.659256E+00	5.303672E+00	2.604088E+05	2.546587E-03	0.000000E+00
5.626524E-12	-3.139525E-01	-3.978343E+00	-1.219659E+05	1.125727E-03	0.000000E+00
5.769763E-12	5.390494E+00	7.663004E+00	4.050412E+05	4.118230E-03	0.000000E+00
5.849762E-12	2.783910E+00	3.127051E+00	3.055601E+05	-3.996130E-03	0.000000E+00
5.966454E-12	1.223840E+00	-4.266287E-01	7.999837E+04	-6.304288E-04	0.000000E+00
6.101869E-12	1.171929E+00	2.968392E+00	1.759315E+05	1.889230E-03	0.000000E+00
6.203509E-12	6.263606E-01	2.283616E+00	9.988812E+04	3.131163E-03	0.000000E+00
6.437344E-12	5.881191E+00	7.117723E+00	4.049629E+05	4.345264E-03	0.000000E+00
6.457343E-12	4.455449E+00	-3.027386E-02	3.743267E+05	-1.099064E-02	0.000000E+00
6.577341E-12	2.004157E+00	6.413227E-01	1.775053E+05	-2.204258E-03	0.000000E+00
6.695262E-12	1.202663E+00	1.410150E+00	1.345137E+05	8.565281E-04	0.000000E+00
6.808585E-12	9.686105E-01	2.110759E+00	1.429560E+05	2.299804E-03	0.000000E+00
6.928491E-12	8.783904E-01	2.300305E+00	1.146047E+05	2.761502E-03	0.000000E+00
7.046399E-12	4.882370E-01	2.502791E+00	8.549994E+04	4.310366E-03	0.000000E+00
7.167627E-12	2.406339E+00	5.769225E+00	3.013147E+05	4.968613E-03	0.000000E+00
7.296616E-12	6.571352E-01	-2.064470E+00	7.214194E+04	5.035924E-04	0.000000E+00
7.407630E-12	1.404073E-01	-2.630196E+00	-2.031395E+04	1.886678E-03	0.000000E+00
7.531514E-12	1.528142E+00	3.153434E+00	1.740936E+05	1.946935E-03	0.000000E+00
7.644033E-12	1.345420E+00	3.063599E+00	1.714316E+05	2.542498E-03	0.000000E+00
7.780775E-12	1.600561E+00	4.338694E+00	2.243552E+05	3.304791E-03	0.000000E+00
7.899959E-12	1.361136E+00	3.937290E+00	2.032834E+05	3.788469E-03	0.000000E+00
8.030162E-12	1.614809E+00	3.955025E+00	2.093461E+05	2.650380E-03	0.000000E+00
8.143168E-12	1.512192E+00	3.473626E+00	1.838816E+05	2.731385E-03	0.000000E+00
8.274843E-12	1.587089E+00	4.335064E+00	2.185652E+05	3.516390E-03	0.000000E+00
8.379301E-12	9.802371E-01	2.980734E+00	1.387596E+05	3.973510E-03	0.000000E+00
8.540470E-12	2.067812E+00	4.918691E+00	2.618319E+05	4.109506E-03	0.000000E+00
8.617783E-12	8.274364E-01	-1.452525E+00	6.398746E+04	7.858465E-04	0.000000E+00
8.736637E-12	2.882183E-01	-1.909730E+00	6.497898E+03	2.357073E-03	0.000000E+00
8.856737E-12	-9.677494E-02	-2.668674E+00	-4.648168E+04	3.320358E-03	0.000000E+00
8.960011E-12	1.053349E+00	-1.527207E+00	1.542307E+05	-2.167559E-04	0.000000E+00
9.102941E-12	1.142593E+00	2.464418E+00	1.293871E+05	3.508100E-03	0.000000E+00
9.201070E-12	-1.462017E-01	-2.413636E+00	-6.372548E+04	3.377774E-03	0.000000E+00
9.345658E-12	3.351733E+00	5.508629E+00	3.176439E+05	5.596288E-03	0.000000E+00
9.460839E-12	1.167117E+00	6.398827E-02	1.131205E+05	1.289108E-03	0.000000E+00
9.581906E-12	5.837559E-01	3.590360E-02	6.407209E+04	3.259334E-03	0.000000E+00
9.698247E-12	4.113925E-01	2.920079E-01	4.396032E+04	4.438385E-03	0.000000E+00
9.826693E-12	1.976532E-01	-3.147496E-01	7.989816E+03	4.711978E-03	0.000000E+00
9.935592E-12	2.878273E-01	-3.467589E-01	4.833005E+04	4.318893E-03	0.000000E+00
1.005264E-11	5.648353E-01	1.209473E+00	9.378100E+04	4.970882E-03	0.000000E+00
1.016913E-11	5.081189E-01	-8.611006E-01	6.853281E+04	3.296718E-03	0.000000E+00
1.029494E-11	5.092629E-01	-9.315511E-01	6.737469E+04	3.314483E-03	0.000000E+00
1.040618E-11	1.013938E+00	2.456434E+00	1.536380E+05	4.976466E-03	0.000000E+00
1.053845E-11	1.070323E+00	2.621817E+00	1.606844E+05	5.070619E-03	0.000000E+00

Appendix B

1.067361E-11	1.121358E+00	2.795807E+00	1.679245E+05	5.199190E-03	0.000000E+00
1.081822E-11	1.243513E+00	3.148542E+00	1.841811E+05	5.448312E-03	0.000000E+00
1.089066E-11	2.783651E-01	-1.491244E+00	1.589848E+03	3.833985E-03	0.000000E+00
1.103353E-11	1.323382E-01	-1.747467E+00	-2.208575E+04	3.928442E-03	0.000000E+00
1.112545E-11	6.924343E-01	-1.210954E+00	1.088389E+05	2.610621E-03	0.000000E+00
1.126094E-11	8.333027E-01	1.581800E+00	9.767112E+04	4.647207E-03	0.000000E+00
1.136560E-11	1.140922E+00	2.937899E+00	1.742401E+05	5.689390E-03	0.000000E+00
1.152517E-11	-6.502366E-02	-1.774199E+00	-4.061190E+04	4.797459E-03	0.000000E+00
1.169112E-11	2.890048E+00	4.658182E+00	2.843601E+05	6.517176E-03	0.000000E+00
1.173112E-11	1.996317E+00	2.908410E+00	2.343399E+05	1.477198E-03	0.000000E+00
1.186080E-11	6.889650E-01	-6.532329E-01	4.901691E+04	3.754127E-03	0.000000E+00
1.196284E-11	9.109507E-01	1.530665E+00	1.056119E+05	5.030975E-03	0.000000E+00
1.210677E-11	5.544320E-01	1.395868E+00	7.548512E+04	6.319132E-03	0.000000E+00
1.220790E-11	-8.540076E-02	-1.210837E+00	-2.001727E+04	5.689252E-03	0.000000E+00
1.234949E-11	-1.256482E-01	-8.210605E-01	-1.901561E+04	6.429341E-03	0.000000E+00
1.245344E-11	1.337247E-01	-5.781483E-01	4.478383E+03	6.099712E-03	0.000000E+00
1.257342E-11	6.058712E-01	1.458286E+00	9.207625E+04	6.226100E-03	0.000000E+00
1.271176E-11	9.263926E-01	2.176552E+00	1.284707E+05	5.885027E-03	0.000000E+00
1.280921E-11	3.513173E-01	-1.708549E+00	2.701863E+03	4.299741E-03	0.000000E+00
1.293284E-11	3.876957E-01	-1.417827E+00	1.055010E+04	4.618213E-03	0.000000E+00
1.305974E-11	3.105274E-01	-1.371261E+00	1.148478E+03	4.877739E-03	0.000000E+00
1.316109E-11	8.100129E-01	1.667515E+00	1.037586E+05	5.445119E-03	0.000000E+00
1.328038E-11	7.429059E-01	1.300370E+00	8.355706E+04	5.639669E-03	0.000000E+00
1.341358E-11	5.796314E-01	-8.998054E-01	8.180337E+04	4.402507E-03	0.000000E+00
1.353967E-11	5.485820E-01	-7.846591E-01	6.621706E+04	4.773989E-03	0.000000E+00
1.365572E-11	1.940172E-01	-7.815877E-01	2.141618E+03	6.156884E-03	0.000000E+00
1.377345E-11	5.842906E-01	1.046880E+00	7.454431E+04	6.112792E-03	0.000000E+00
1.388292E-11	4.440594E-01	-7.476458E-01	4.667602E+04	5.337402E-03	0.000000E+00
1.401496E-11	6.961120E-01	1.443892E+00	8.112575E+04	6.450690E-03	0.000000E+00
1.412756E-11	-9.043378E-02	-1.445009E+00	-2.650251E+04	6.192327E-03	0.000000E+00
1.424915E-11	-3.802472E-01	-1.896065E+00	-7.034500E+04	7.517770E-03	0.000000E+00
1.453244E-11	5.015199E+00	5.114903E+00	3.113939E+05	8.502625E-03	0.000000E+00
1.455243E-11	3.991223E+00	4.585613E-02	2.770188E+05	-4.978273E-03	0.000000E+00
1.461242E-11	3.146508E+00	2.392066E+00	2.421767E+05	-6.767462E-04	0.000000E+00
1.473761E-11	1.609648E+00	8.668871E-01	1.233102E+05	3.255885E-03	0.000000E+00
1.487037E-11	8.892568E-01	8.210591E-01	9.491412E+04	5.343359E-03	0.000000E+00
1.500712E-11	6.914332E-01	8.901687E-01	7.334606E+04	6.445758E-03	0.000000E+00
1.511932E-11	1.628138E-01	-5.461057E-01	8.452785E+03	6.703839E-03	0.000000E+00
1.520951E-11	3.016017E-01	-7.076451E-01	2.491710E+04	6.456625E-03	0.000000E+00
1.533362E-11	7.960721E-01	1.668387E+00	1.079819E+05	6.951418E-03	0.000000E+00
1.547415E-11	9.526151E-01	1.734936E+00	1.097041E+05	6.642208E-03	0.000000E+00
1.556613E-11	1.030058E+00	2.234645E+00	1.319390E+05	7.049620E-03	0.000000E+00
1.571213E-11	1.149617E+00	2.259413E+00	1.367612E+05	6.487798E-03	0.000000E+00
1.580790E-11	6.635709E-01	-9.675603E-01	8.144800E+04	5.047638E-03	0.000000E+00
1.594008E-11	1.293880E-01	-9.045351E-01	1.084415E+04	6.552365E-03	0.000000E+00
1.607094E-11	7.590342E-01	1.749841E+00	1.085284E+05	7.941712E-03	0.000000E+00
1.619319E-11	7.081732E-01	1.452612E+00	9.864506E+04	7.372685E-03	0.000000E+00
1.629157E-11	2.379438E-01	-6.298687E-01	2.548341E+04	6.549377E-03	0.000000E+00
1.642551E-11	6.674834E-01	1.445780E+00	9.667044E+04	7.878073E-03	0.000000E+00
1.655859E-11	6.722011E-01	1.352268E+00	9.507019E+04	7.573705E-03	0.000000E+00
1.665544E-.1	1.959940E-01	-5.462503E-01	2.209391E+04	6.863575E-03	0.000000E+00
1.677690E-11	5.772628E-01	1.163127E+00	8.333500E+04	7.894076E-03	0.000000E+00
1.689415E-11	2.464822E-01	2.685646E-01	2.154674E+04	8.006386E-03	0.000000E+00
1.704351E-11	1.676113E-01	5.823381E-02	2.383457E+04	8.035038E-03	0.000000E+00